

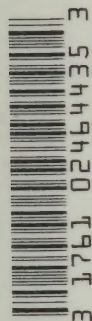
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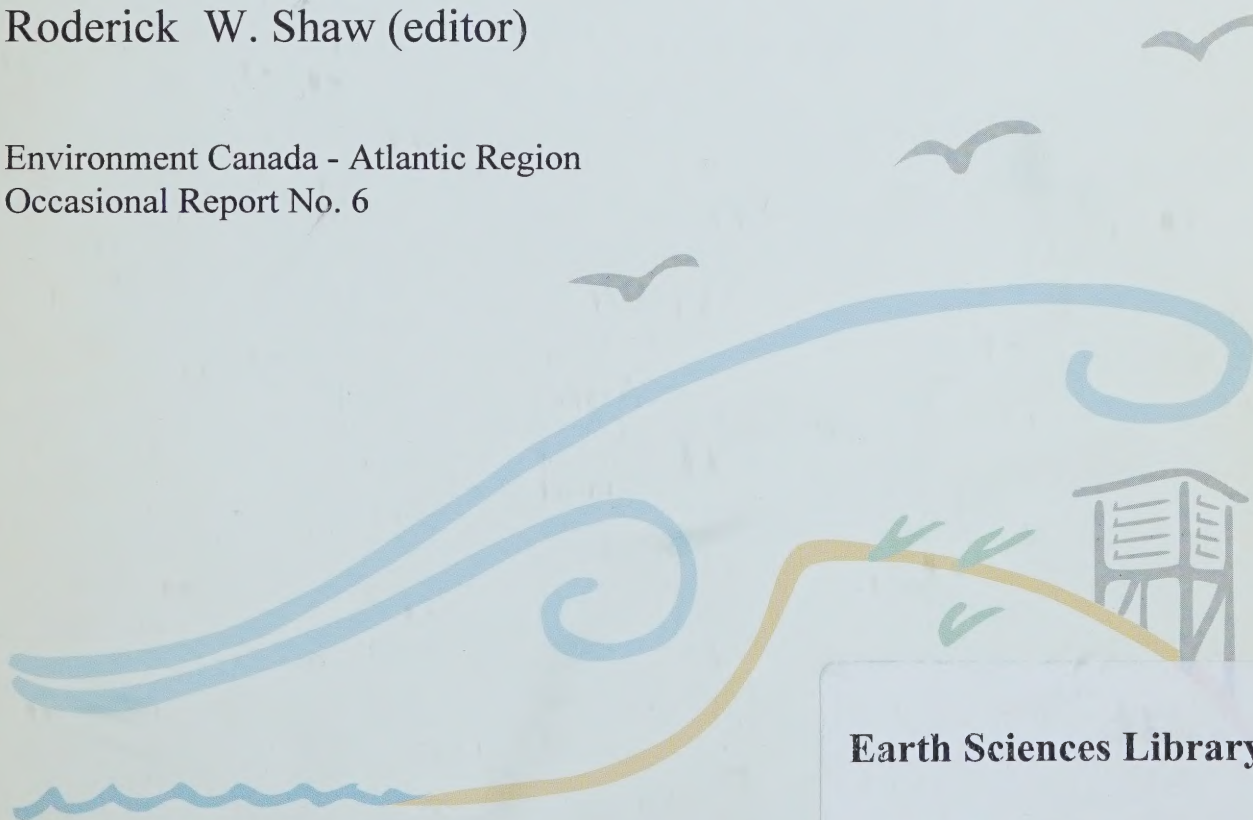


Science and Policy Implications of Atmospheric Issues in Atlantic Canada

Workshop Proceedings
Halifax, Nova Scotia
November 28-30, 1995

Roderick W. Shaw (editor)

Environment Canada - Atlantic Region
Occasional Report No. 6



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**SCIENCE AND POLICY IMPLICATIONS
OF
ATMOSPHERIC ISSUES IN ATLANTIC CANADA:**

Proceedings of a Workshop

Halifax, Nova Scotia

28-30 November 1995

prepared for

**Environment Canada
Atlantic Region**

by

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FOREWORD

The conception and organization of this workshop was a collaborative effort among various elements of Environment Canada, Atlantic Region. The organizing committee consisted of Dr. Thomas Clair, Environmental Conservation Branch, Sackville, New Brunswick; Mrs. Billie Beattie, Atmospheric Environment Branch, Bedford, Nova Scotia; and Mr. William Moores, Environmental Protection Branch, Dartmouth, Nova Scotia. Funding for the workshop was provided by all three above components of Environment Canada, Atlantic Region and by the Science Assessment and Policy Integration Division, Atmospheric Environment Service, Downsview, Ontario. The writer of this report was assisted by two rapporteurs from Dalhousie University: Dr. Cindy Staicer of the Department of Biology and Ms. Jacqueline Witte of the Department of Oceanography.

TABLE OF CONTENTS

	<u>Page</u>
Executive Summary	i
1. Purpose and Organization of the Workshop	1
2. The Workshop in the Context of Atmospheric Science in Atlantic Canada	5
3. The Workshop in the Context of the Planning of Research and Policy in the Atlantic Region	9
4. Regional Acidification	11
<i>a) The present situation with respect to science</i>	11
<i>b) The present situation with respect to policy</i>	13
<i>c) Workshop deliberations</i>	14
5. Low-level Oxidants	21
<i>a) The present situation with respect to science</i>	21
<i>b) The present situation with respect to policy</i>	25
<i>c) Workshop deliberations</i>	26
6. Stratospheric Ozone Depletion	33
<i>a) The present situation with respect to science</i>	33
<i>b) The present situation with respect to policy</i>	37
<i>c) Workshop deliberations</i>	39

	<u>Page</u>
7. Hazardous Air Pollutants	43
<i>a) The present situation with respect to science</i>	43
<i>b) The present situation with respect to policy</i>	45
<i>c) Workshop deliberations</i>	48
8. Climatic Change	51
<i>a) The present situation with respect to science</i>	51
<i>b) The present situation with respect to policy</i>	59
<i>c) Workshop deliberations</i>	60
9. Overall Conclusions and Recommendations of the Workshop	63
Appendix A: Workshop Agenda	67
Appendix B: Workshop registrants	73
Appendix C: Abstracts and Summaries of Poster and Verbal Presentations: Day 1 - Regional Acidification and Low-level Oxidants	83
Appendix D: Abstracts and Summaries of Poster and Verbal Presentations: Day 2 - Stratospheric Ozone Depletion and Hazardous Air Pollutants	101
Appendix E: Abstracts and Summaries of Poster and Verbal Presentations: Day 3 - Climatic Change	121

EXECUTIVE SUMMARY

1. The Purpose and Organization of the Workshop

The workshop "Science and Policy Implications of Atmospheric Issues in Atlantic Canada" was held in Halifax, Nova Scotia on 28-30 November 1995. Its purpose was:

- 1) to review the current science and policy status of five atmospheric issues in Atlantic Canada: acidification, low-level oxidants, stratospheric ozone depletion, hazardous air pollutants and climatic change
- 2) following the above review to suggest realignments of research and policy priorities
- 3) to strengthen the regional network of scientists and policymakers.

One hundred three scientists and policymakers from within and outside the Atlantic region participated in the workshop. Most (75) were from the federal government; 8 were from provincial governments; 14 were from academia; and 6 were from the private sector.

The format of the workshop was as follows:

- each day was devoted to one or two atmospheric issues
- the morning of each day was devoted to verbal presentations to update the participants on the current international, national and regional status of science and policy with respect to the atmospheric issue(s) to be dealt with that day
- posters showing current research results for the issue of the day, with emphasis on regional work, were displayed throughout the day. Authors were available for discussion during the lunch break. The posters were changed each day.
- the afternoon of each day was devoted to discussions by two concurrent work groups. The discussion questions were as follows:

Question 1: In considering this environmental issue (e.g., acidification, climatic change) what aspects (e.g., loss of habitat, sea level rise) are of the greatest importance in the Atlantic Region?

Question 2: In view of the aspects of the environmental issue that have been identified in dealing with Question 1, what results, in terms of a) improvements of our understanding of the environment, and b) changes in the environment, would we like to see from our efforts in the next five or ten years?

EXECUTIVE SUMMARY

Question 3: What activities are needed to achieve these results? Which ones are essential and which are optional? Are our monitoring systems adequate to define the risks to ecosystems? Do we have the necessary skills and capabilities to carry out these activities? How do we integrate complementary skills and capabilities in the federal and provincial governments, the universities and the private sector to achieve the most results for our efforts? How do we ensure that we address (as much as possible) more than one environmental issue in our activities, and the reporting of our results?

The purpose of this report is to summarize the proceedings of the workshop and, in particular, in the context of the Atlantic region - it is NOT intended to be a comprehensive textbook on these five particular atmospheric issues. The main body of the text summarizes: 1) the verbal and poster presentations on the present situation with respect to a) science and b) policy; and 2) the results of the afternoon work group discussions based upon the three questions listed above. Abstracts for the verbal and poster presentations that were submitted by the authors are given in appendices. This Executive Summary will focus on the findings of the afternoon workshops.

2. Regional Acidification

Question 1: What aspects of regional acidification are of the greatest importance in the Atlantic Region?

1. The health aspects of sulphate aerosols, in particular, the interaction of aerosols with oxidants in Saint John, New Brunswick. (This is a common issue with low-level oxidants.)
2. Acidic fog along the Atlantic Coast including the Bay of Fundy.
3. The joint effect of acidic deposition and increased UV-B radiation in brown (organic) lakes.
4. The loss of aquatic habitat for species such as salmon.
5. The fact that the presently planned reductions in acidifying emissions will not bring acidic deposition within critical loads in the Atlantic Region.

EXECUTIVE SUMMARY

Question 2: What are the results, in terms of a) improvements of our understanding of the environment, and b) changes in the environment, that we would like to see from our efforts in the next five to ten years?

1. Improved understanding of interactions between acidifying pollution and other issues such as oxidants.
2. Improved understanding of any effects of sulphate aerosols and oxidants on health in an urban area such as Saint John.
3. Improved understanding of the mechanisms between acidic deposition (including sulphates and nitrates) and aquatic acidification, including brown waters.
4. Continued long term records of acidic deposition, water quality and populations of aquatic species to monitor the effects of continued deposition and future changes in emissions.
5. Continued reductions of acidic deposition in the Atlantic Region to values that exceed critical load by amounts smaller than at present.

Question 3: What activities are needed to achieve these results?

1. An intensive study of the health effects of urban air quality in Saint John.
2. Development of Integrated Assessment Models (IAMs) that take into account time-dependency (chronic and episodic effects), linkages among various pollutants including sulphate and nitrate and changes in UV-B radiation.
3. Maintenance of existing long term atmospheric and aquatic monitoring, and periodic re-evaluation of regional status.
4. A more relevant assessment of critical loads for brown waters.
5. Development of emission strategies within and outside the Region to reduce acidifying emissions.

EXECUTIVE SUMMARY

3. Low-level Oxidants

Question 1: What aspects of low-level oxidants are of greatest importance in the Atlantic Region?

1. An improved knowledge of the behaviour of locally produced precursors in an aged air mass, and the effects of the maritime boundary layer upon formation and dispersion.
2. The combined effects of oxidants and sulphate aerosols on human health, especially in urban areas such as Saint John. (This is a common issue with regional acidification.)
3. The effects of oxidants, combined with climatic change, on forest species (including biodiversity) in the Atlantic Region.
4. The need for an improved ability to assess, over an extended period into the future, changes in air quality and receptors due to changes in oxidant precursors.

Question 2: What are the required results, in terms of a) improvements of our understanding of the environment, and b) changes in the environment, that we would like to see from our efforts in the next five to ten years?

1. An improved knowledge of the behaviour of locally produced precursors in an aged air mass, and the effects of the maritime boundary layer upon formation and dispersion.
2. Improved knowledge of the combined effects upon human health of oxidants and sulphate aerosols.
3. An assessment of the effects of low-level oxidants, over a long time spanning the past and the future, on air quality and receptors.

Question 3: What activities are needed to achieve these results?

1. Development of integrated oxidant models capable of simulating long-range transport, formation from locally emitted precursors, transport and dispersion within the maritime boundary layer, and effects upon receptors.
2. Participation of Canadian scientists in the 1996 North American Research Strategy for Tropospheric Ozone (NARSTO) field study in the Atlantic Region and elsewhere to obtain data to improve model predictions.
3. Maintenance of long-term quantitative monitoring of air quality and forest species.

EXECUTIVE SUMMARY

4. Establishment of improved dose-response relationships and critical levels for the effects of low-level oxidants on both human and terrestrial plants, including forests. These relationships need to be determined for conditions that exist in the Atlantic Region and then be used to select sensitive indicators.

5. Formation of partnerships among governments, academia, industry and the public. Partnerships make good sense because of the current reduction of government budgets, and the fact that both the public and private sectors have a vested interest in maintaining healthy natural and human environments.

4. Stratospheric Ozone Depletion

Question 1: What aspects of ozone depletion are of greatest importance in the Atlantic Region?

1. Past and future changes in the incoming flux of UV-B radiation in the Atlantic Region
2. Effects of changes in UV-B radiation in the natural and agricultural ecosystems in the Atlantic Region.
3. Effects in human beings from changes in UV-B radiation. Much is known generally about effects of UV-B radiation on the skin and the eyes, but there is little or no information specific to the Atlantic Region.

Question 2: What are the required results, in terms of a) improvements of our understanding of the environment, and b) changes in the environment, that we would like to see from our efforts in the next five to ten years?

1. Improved, continuous time series of UV-B radiation and ozone layer measurements in the Region with adequate spatial coverage. This information would not only be needed to monitor the effects of programs to reduce emissions of ozone-depleting substances, but would also be needed to continue the implementation of the Canadian "UV Index"TM.
2. Increased understanding and quantification of the effect of UV-B radiation on forest and agricultural ecosystems, including linkages to other issues such as regional acidification and climatic change. This information would be useful in assessing the potential economic damage to the region's resources due to increased UV-B radiation in the future.
3. Better dose-response relationships and indicators of effects of UV-B radiation that are specific to the Atlantic Region. Little regional information is available, especially for forest species. This information would be needed to predict the possible changes in damage due to changes (positive and negative) in UV-B radiation.

EXECUTIVE SUMMARY

4. Minimization of biological effects through the development of crops that are more UV-B resistant.
5. Minimization of the effects of UV-B radiation upon humans.

Question 3: What activities are needed to achieve these results?

1. Monitoring of UV-B radiation by ground stations and satellites, if possible through collaboration with the Environmental Monitoring and Assessment Network (EMAN).
2. Field studies of effects of increased UV-B radiation on ecosystems at existing sites such as Kejimikujik. These studies would make use of the measurements discussed in Point 1 above and would follow as much as possible an ecosystem approach.
3. Selection of UV-B resistant crops at agricultural research stations.
4. Promotion of sun-safe behaviour through publicization of the Canadian UV Index™ and public education about how to minimize exposure to UV-B radiation.
5. Support of national programs on eliminating and minimization of the use of Ozone Depleting Substances (ODSs).

5. Hazardous Air Pollutants

Question 1: What aspects of hazardous air pollutants are of greatest importance in the Atlantic Region?

1. Our lack of knowledge about hazardous air pollutants (HAPs) in the Atlantic Region, specifically:
 - emissions and atmospheric concentrations of HAPs in the region
 - deposition from the atmosphere
 - relative importance of regional and extra-regional sources
 - penetration of HAPs into natural and human ecosystems
2. The importance in the Atlantic Region of mercury as a hazardous air pollutant is not well known. Mercury is considered to be an emerging environmental issue.

EXECUTIVE SUMMARY

Question 2: What are the required results, in terms of a) improvements of our understanding of the environment, and b) changes in the environment, would we like to see from our efforts in the next five to ten years?

1. An assessment of the relative importance in the Atlantic Region of airborne toxic pollutants, including mercury, in terms of emissions, concentrations, deposition and toxicity.
2. An assessment of the relative importance of sources of hazardous air pollutants within and outside of the Atlantic Region. This is important to determine the importance of control measures within the Region.

Question 3: What activities are needed to achieve these results?

1. Establishment of a team, horizontally integrated among federal and provincial government agencies and others, to:
 - develop a definition for hazardous air pollutants (HAPs) relevant to the Atlantic Region
 - examine existing national and regional data on emissions, concentrations and deposition
 - select the HAP(s) of greatest concern in the Region
2. Establishment, as a test case, an ecosystem study for mercury, using if possible an existing site. One possible site for such a study could be the EMAN site at Kejimikujik, Nova Scotia.

6. Climatic Change

Question 1: What aspects of climatic change are of greatest importance in the Atlantic Region?

1. Despite the uncertainty in the projections of climatic change in the Atlantic Region, it is important to have an estimate of the sensitivity of Atlantic Canada resources to climatic changes in either direction. Such resources include agriculture, forests, wildlife, the fishery, coastal infrastructure, transportation, tourism and the human population.
2. It is important to continue the database of climatic variables to enable us to distinguish natural climatic variability from changes caused by human activities.

EXECUTIVE SUMMARY

Question 2: What results, in terms of a) improvements of our understanding of the environment, and b) changes in the environment, would we like to see from our efforts in the next five to ten years?

1. A list of components of the Atlantic Canada environment (both natural and human) that are sensitive to changes to climatic variables (in either direction), and those which are not. Indicators would include biodiversity, health, productivity, availability for human use, and susceptibility to changes in sea level and storm surges.
2. Based upon Item 1 above, protective and adaptive measures including lifestyle changes that will be robust with respect to uncertainties in climatic change projections. Because of the uncertainty in predictions by Global Circulation Models of changes in regional climate, it would be prudent to take measures that would make us less susceptible to climatic change in either direction.
3. Continuance of the database of climatic variables with sufficient temporal and spatial resolution to detect any anthropogenic changes and allow one to estimate the risk to the sensitive components of the environment.

Question 3: What activities are needed to achieve these results?

1. Formation of an interdisciplinary and multisectoral (public, private, academia) group to develop a matrix of sensitivity of various components of the environment of the Atlantic Region to climatic change. One dimension of the matrix would be the aspect of the resource (using indicators such as freshwater availability or forest biodiversity); the other would be climatic variables such as temperature, precipitation, sea level rise or storm surges.
2. Given the results from the sensitivity matrix above, the group in Item 1 will suggest protective and adaptive measures for the sensitive components of our ecosystem.
3. The multisectoral group in Item 1 will oversee the monitoring of climatic changes in the region. An attempt will be made to link regional climatic changes with those occurring on a continental and global scale.

EXECUTIVE SUMMARY

7. Overall Conclusions and Recommendations of the Workshop

Although some of the findings of the workshop were relevant to only one or two issues, there were several strong common threads running through all of them, and which merit being highlighted as overall conclusions of the workshop. These overall conclusions, which are listed below, will hopefully serve as guidance for the future planning of atmospheric research and policy in the Region.

1. The ecosystem approach should be followed as much as possible in the planning of research. This has been done for the past 20 or more years in, for example, Kejimikujik National Park and should be continued. Because ecosystems are usually subject to more than one atmospheric stress, it makes sense to focus efforts in one geographical area to better determine the linkages and synergisms among the various stresses. Monitoring of atmospheric qualities (see Item 2 below) and ecosystem responses in the Region could yield dose-response relationships for combinations of stresses that will be useful in establishing environmental targets that are relevant to the Region. For example, the workshop brought out the need for better information on critical loads for acidic deposition on the brown freshwaters that are common in the Region. In addition, more information is needed on the effect of increased UV-B radiation on forest species. It was also suggested that an ecosystem study on mercury be initiated as a test case. Ecosystem studies are the way to bring scientists from various sectors together to study more than one problem.

2. Throughout the workshop, it was stressed that it is essential that a commitment be made for continuous, long term monitoring of atmospheric qualities that are relevant to all of the atmospheric issues: acidic deposition, tropospheric oxidants, UV-B radiation, total column ozone, hazardous air pollutants and climatic variables, as well as the anticipated ecosystem responses. All too often in the past, badly needed long-term data simply do not exist. Some of these long-term measurements could be made as part of the ecosystem studies and be incorporated in the Environmental Monitoring and Assessment Network (EMAN). Not only are such measurements needed to better define a problem, such as in the case of hazardous air pollutants, but they are needed to assess the effects of emission controls with respect to, for example, regional acidification, low-level oxidants and stratospheric ozone depletion.

3. The development of Integrated Assessment Models (IAMs) that are relevant to the Region should be encouraged. These models should address more than one atmospheric issue, such as regional acidification and low-level oxidants, and should include ecosystem effects. The development of these models should make use of information gained from ecosystem studies, long-term monitoring and Canadian participation in projects such as the North American Research Strategy for Tropospheric Ozone (NARSTO). These models could be used to assess the possible effects of proposed emission control policies and, when combined with economic data, to develop cost-effective strategies. This could be especially useful for regional acidification, since deposition is presently above critical loads in the Atlantic Region.

EXECUTIVE SUMMARY

4. With respect to climatic change, it was apparent that the projections by General Circulation Models (GCMs) of changes in regional climate due to increasing greenhouse gas concentrations are very uncertain, even to the direction of the changes. Therefore, it was concluded that the most prudent step to take would be to form a multidisciplinary and multisectoral group to develop a matrix of sensitivity of various regional resources, for example freshwater availability or forest diversity, to climatic changes *in either direction*. This activity would make use of existing monitoring and modelling results, and ecosystem studies. This group could then suggest protective and adaptive regional measures against climatic change.

5. Finally, in developing regional research and policy, it would be prudent to form as many partnerships as possible among various elements of the public and private sectors, including academia and industry. Not only would pooling intellectual and financial resources be beneficial in these days of restraint, but it could foster an atmosphere of mutual rather than adversarial interest in addressing atmospheric issues.

1. The Purpose and Organization of the Workshop

The workshop "Science and Policy Implications of Atmospheric Issues in Atlantic Canada" was held in Halifax, Nova Scotia on 28-30 November 1995. Its purpose was:

- 1) to review the current science and policy status of five atmospheric issues in Atlantic Canada: acidification, low-level oxidants, stratospheric ozone depletion, hazardous air pollutants and climatic change
- 2) following the above review to suggest realignments of research and policy priorities
- 3) to strengthen the regional network of scientists and policymakers.

One hundred three scientists and policymakers from within and outside the Atlantic region participated in the workshop. A list of participants is shown in Appendix B. Most (75) were from the federal government; 8 were from provincial governments; 14 were from academia; and 6 were from the private sector.

Appendix A shows the workshop agenda. The format of the workshop was as follows:

- each day was devoted to one or two atmospheric issues
- the morning of each day was devoted to verbal presentations to update the participants on the current international, national and regional status of science and policy with respect to the atmospheric issue(s) to be dealt with that day
- posters showing current research results for the issue of the day, with emphasis on regional work, were displayed throughout the day. Authors were available for discussion during the lunch break. The posters were changed each day.
- the afternoon of each day was devoted to discussions by two concurrent work groups. The discussion questions were as follows:

Workshop on Atmospheric Issues in Atlantic Canada

Question 1: *In considering this environmental issue (e.g., acidification, climatic change) what aspects (e.g., loss of habitat, sea level rise) are of the greatest importance in the Atlantic Region?*

- *which aspects are a) old, b) ongoing or c) emerging?*

Question 2: *In view of the aspects of the environmental issue that have been identified in dealing with Question 1, what results, in terms of a) improvements of our understanding of the environment, and b) changes in the environment, would we like to see from our efforts*

- *in the next five years?*
- *in the next ten years?*

Question 3: *What activities are needed to achieve these results? Which ones are essential and which are optional?*

- *are our monitoring systems adequate to define the risks to ecosystems?*
- *do we have the necessary skills and capabilities to carry out these activities?*
- *how do we integrate complementary skills and capabilities in the federal and provincial governments, the universities and the private sector to achieve the most results for our efforts?*
- *how do we ensure that we address (as much as possible) more than one environmental issue in our activities, and the reporting of our results?*
 - *through ecosystem studies?*
 - *through integrated modelling, etc.?*

The purpose of this report is to summarize the proceedings of the workshop, in particular, in the context of the Atlantic region - it is NOT intended to be a comprehensive textbook on these five particular atmospheric issues. Sections 2 and 3 outline some of the thinking leading to the workshop. Sections 4 to 8 summarize for each day of the workshop: 1) the verbal and poster presentations on the present situation with respect to a) science and b) policy; and 2) the results of the afternoon work group discussions based upon the three questions listed above.

Abstracts for the verbal and poster presentations that were submitted by the authors are given in Appendices C, D and E. Wherever possible, references are made in the text to these abstracts.

Finally, Section 9 will present the overall findings and recommendations of the workshop.

Workshop on Atmospheric Issues in Atlantic Canada

2. The Workshop in the Context of Atmospheric Science in Atlantic Canada

a) General

Despite the fact that environmental research has fostered much more interdisciplinary collaboration that had occurred in the past, all too often the significant atmospheric environmental issues of our day such as climatic change, stratospheric ozone depletion, acidic deposition, and hazardous air pollutants are addressed on a single issue basis. This has occurred in a natural way because each issue has its own constituency, methodologies (such as models), and policy approaches. Linkages among the issues, although often acknowledged philosophically, have not truly been incorporated into the scientific and policy research. As a result, the policies that have emerged to address one atmospheric issue in an optimal way may not have been very helpful in addressing another, and may even have been counter-productive. For example, the increased use of methane as a fuel to reduce carbon dioxide emissions (and the greenhouse effect) could, if excessive leakages of methane were allowed to occur, lead to increased atmospheric concentrations of methane, itself a powerful greenhouse gas and a player in the formation of tropospheric ozone. Increasing tropospheric methane will also increase the concentrations of the hydroxyl radical, the most important gas-phase oxidizer of sulphur dioxide to sulphuric acid.

In March 1995 a workshop, sponsored by Environment Canada and organized by the Institute for Environmental Studies at the University of Toronto, took place in Toronto to look at different methods that may be used to undertake integrated assessments of a number of *linked* atmospheric issues rather than a single issue.¹ An integrated assessment will better the chances that more integrated policies to address them will emerge. Two of the potential tools that were discussed at the workshop were: biogeochemical models and; the ecosystem approach.

¹ATMOSPHERIC CHANGE IN CANADA: *Assessing the Whole as Well as the Parts*. R. E. Munn, Editor. Workshop Report, Institute for Environmental Studies, University of Toronto, Toronto, Ontario M5S 1A4, July 1995, 36 pp.

b) Biogeochemical models

Traditionally, biogeochemical (BGC) models represent the cycling of an single substance (often an element) among various reservoirs in the natural and human environment. BGC models provide not only quantitative estimates of the stocks and flows of the substance but also describe the processes that cause these stocks and flows to change. To be truly integrated even in the context of a single substance, BGC models should include not only information on the cycling of the substance but the ecological responses as well. BGC models can become very complex if non-linearities and feedbacks are included.

BGC models can be used to link different atmospheric issues if they consider more than one substance and include those parts of the cycles of the substances that overlap. For example, as mentioned above, methane, in addition to being a greenhouse gas in its own right, takes part in the chemical modelling of both tropospheric ozone and the acidification from sulphur and nitrogen oxides. A well-integrated BGC model which includes more than one substance, non-linearities, feedbacks, and ecological responses, really approaches the ecosystem approach (to be discussed below).

Integrated Assessment Models (IAMs) are often based upon complex BGC models but play a very important role in communicating the results of BGC models to policymakers. An example of an IAM is the Regional Acidification Information and Simulation (RAINS) model which is used in Europe to formulate and assess strategies to reduce acidic deposition (Reference to this model was made by G. Fenech in the Halifax workshop in the session on regional acidification, see Section 4.1 (a)). RAINS comprises several modules from one dealing with energy use, emissions and costs of control through an atmospheric transport and deposition module to several modules dealing with environmental effects such as fresh water acidification and risk of forest damage. Each module is based upon a fairly complicated BGC model, but expresses its results in a relatively simple way.

The Integrated Model to Assess the Greenhouse Effect (IMAGE), developed at the Netherlands Institute for Public Health and Environmental Protection, is a good example of an IAM dealing with the issue of climatic change. IMAGE has modules dealing with both anthropogenic and natural emissions of several greenhouse gases, their biogeochemical cycling, their radiative forcing of the atmosphere, and modules on the effects of temperature change on sea level, forests and the terrestrial biosphere.

c) The ecosystem approach

The Toronto workshop proposed that, in an ecosystem approach, the ecosystem may be broken down into driving variables, processes and the resulting properties. Driving variables could be temperature, precipitation, frequency of extreme meteorological events, and atmospheric deposition. Properties may include the composition, spatial and temporal distribution of components such as soil, freshwater, and biota. Processes such as transpiration, photosynthesis, and carbon, sulphur and nitrogen cycling, in combination with the hydrological cycle, link driving variables with properties. The boundaries of the ecosystem approach are chosen so that as many as possible of the processes linking the driving variables and the properties are contained within them. Because of the transboundary nature of many atmospheric issues, this is usually not entirely possible. The human component may or may not be included in the ecosystem approach. In a sense, the ecological approach may form a framework in which to carry out biogeochemical modelling.

d) Usefulness of the above two approaches

The Toronto workshop concluded that both biogeochemical models and the ecosystem approach were useful devices for integrating atmospheric issues. They can point out the important cross-linkages among the various air issues, and where better scientific knowledge is needed. In fact integrating more than one issue in a scientific model or in an ecosystem study may have a synergistic effect upon scientific knowledge - for example, one can not fully understand the scientific processes in acidification unless the oxidant cycle is included as well in the model.

Workshop on Atmospheric Issues in Atlantic Canada

Apart from the scientific product i.e., an integrated model or increased scientific knowledge, the process of building the model can be a device to bring together scientists from different disciplines and sectors, as well as decision-makers who may have a vested interest in using the model for helping to develop and assess alternative policies. This was made clear during the building of RAINS and of IMAGE, processes that involved scientists of many disciplines over periods of at least several years.

Finally, the Toronto workshop concluded that there is much to be gained by addressing a specific environmental problem in a particular locality or region such as an ecosystem. Nothing can focus thinking better than a specific challenge.

e) The situation in the Atlantic Region

Although there has not been an integrated assessment model that has been designed specifically for the Atlantic Region, there have been ecosystem studies. The most obvious example is the studies that have been carried out at Kejimikujik National Park in Nova Scotia in connection with regional acidification and exposure to regional-scale tropospheric oxidants. The studies at Kejimikujik have yielded a wealth of information on the effects of acidic deposition on ecosystems. As will be seen in Sections 4 to 8, there are opportunities to expand both integrated assessment modelling and ecosystem studies to other atmospheric issues in the Region.

3. The Workshop in the Context of Planning Research and Policy in the Atlantic Region

The Ecological Planning Framework (EPF) has been under development within Environment Canada Atlantic Region for the past couple of years. It is a systematized process for the planning and implementation of programs and projects at a variety of scales (e.g. local, regional, national, international and global). To be relevant, it must afford individuals the ability to establish program priorities, the flexibility to respond to new challenges and the opportunity to see where their activities and functions fit into the larger picture. The EPF will not be accepted if it is seen as just another planning exercise to justify ongoing activities and does not help individuals to perform their work to effectively address the *relevant* current and anticipated environmental issues. In short, the EPF starts with basic questions about the environmental issues of most concern to us and ends with the activities and skills necessary to address them.

The EPF is designed around the development of six major components. These components are: Environmental Issues, Integrated Results, Products and Services, Activities, Required Skills and Functions, and Implementation.

Environmental Issues: Provides a top level view of the major environmental issues, or resource management concerns, which should be given priority action. *I.e., What are the most important current and anticipated regional environmental issues?*

Integrated Results: Requires a management objective which will provide a clear direction and focus (i.e. defined results) for program development and implementation. *I.e., What environmental improvements do we want to achieve with respect to priority issues in the next few years?*

Products and Services: *I.e., What products in terms of research results or environmental policies will bring about the desired results?* Priorities can be established to indicate which products are of prime importance.

Workshop on Atmospheric Issues in Atlantic Canada

Activities: Requires identification of all activities or program elements needed to develop the stated products. Activities could be ranked on the basis of need (i.e. essential, integrated or optional) *I.e., What do we really have to do to get the needed research results or environmental policies?*

Skills/Functions: Requires an indication of the functions and skills needed to complete the identified activities. This will provide all of those working in the environmental field with a sense of where they belong and how they could contribute to the above activities. In addition, gaps in our capability to carry out the required activities can be identified and addressed resolved through training, contracting for service, development of partnerships, etc. *I.e., Do we have the capability to carry out the required activities and, if not, how can we obtain it or encourage others to carry them out?*

Implementation: Activities can be focussed into a more cohesive form on an appropriate ecological boundary system such as a watershed. *I.e., Where can we best focus our efforts?*

The workshop provided one of the first opportunities to assess the potential of the EPF in addressing regional atmospheric issues. The three work group questions that were listed in Section 1 were designed specifically to fit into the Ecological Planning Framework.

4. Regional Acidification

a) The present situation with respect to science

i) Observed concentrations and deposition

Statistically significant decreases of 28 to 40% in sulphate concentration in precipitation (corrected for sea-salt) have been observed since the mid- to early 1980s at four Canadian Air and Precipitation Monitoring (CAPMon) stations in Nova Scotia, New Brunswick and the island of Newfoundland (Beattie and Keddy, p.85). As a result, sulphate deposition has generally decreased in the Atlantic Region; in 1980 most of the region received deposition greater than 12 kg SO₄/ha/yr while in recent years most of the region has received less than this value.

This decrease is of the same order as the decreases (16.5% between 1980 and 1992 (Beattie and Keddy, p.85)) in sulphur dioxide emissions brought about internationally by Canada and the U.S. and, within Canada, among the eastern provinces. D. McKay reported a correlation of 0.83 between sulphate deposition and sulphur emissions over a 14-year period.

No significant trends were observed in nitrate deposition at two stations in the region (Kejimikujik NS and Bay d'Espoir NF between 1983 and 1989, (Clair *et al*, p.88), and D. McKay reported that there was a weaker correlation (0.22) between nitrate deposition and emissions of nitrogen oxides.

It was pointed out in the afternoon work group discussion that aerosol sulphates could combine with the fog that is found frequently over Atlantic coastal areas to form acidic fog. If these were inhaled, especially in conjunction with elevated concentrations of low-level oxidants, human health could be adversely affected.

ii) Freshwater effects

Despite the above decreases in sulphate deposition, much of the Atlantic Region is receiving deposition that is in excess of the "critical load", which is estimated to be less than 8 kg SO₄/ha/yr (Beattie and Keddy, p.85). Jeffries (p.91) stated that critical loads for aquatic ecosystems are based upon a freshwater pH of 6.0, below which many species of fish begin to disappear. He pointed out, however, that these relationships between atmospheric deposition and lake pH were developed mainly for clear lakes and more work needs to be done for the brown, organic lakes that are common in the Atlantic Region. Jeffries (p.91) stated that emission reductions beyond those undertaken in 1985 are needed to reverse the aquatic acidification that has already taken place.

Watt (p.99) found a possible link between freshwater acidification and climatic change. His hypothesis is that increasing temperatures lead to decreased dissolved organic carbon (DOC), increased pH and an increase in juvenile salmon. Therefore, the observed increase in salmon numbers may be due to increasing temperatures as well as a decrease in acidic deposition. When Mount Pinatubo erupted in June 1992, the resulting decrease in temperature may have led to a temporary reversal of the recovery of the salmon.

iii) Terrestrial effects

With respect to terrestrial ecosystems, Arp (p.84) proposed a model to calculate critical loads of S and N for upland forests. He found that, in New Brunswick, critical loads for S and N were exceeded for the Fundy and Northumberland coasts, respectively. The method of tree harvesting can exacerbate the effects of acidic deposition. Arp's model calculated that harvesting of upland forests would increase the exceedances of deposition over critical loads. Mahendrappa *et al* (p.94) found that whole tree harvesting could lead to a loss of nutrients, rapid decomposition of soil organic matter, increased nitrification, increased soil acidity and loss of base cations.

iv) Modelling

Modelling of the long range atmospheric transport and deposition of acidifying pollutants affords one the opportunity to predict the environmental consequences of future changes in emission patterns, and to formulate policies to reduce the effects of regional acidification. D. McKay described the Acidic Deposition and Oxidants Model (ADOM), developed jointly by Environment Canada and Ontario Ministry of Environment and Energy. It is a modular model that is capable of developing source-receptor relationships with respect to acidic deposition in North America. It has been successful in predicting sulphates and nitrates for periods of longer than one month but there is a need for further testing of the model.

Fenech (p.89) described the use in Europe of the Regional Acidification INformation and Assessment (RAINS) model that has been used by the UN Economic Commission for Europe (UN-ECE) to formulate and assess emission control strategies, including minimum cost strategies to meet specific deposition targets. An integrated assessment model (IAM) which, like RAINS, includes modules for receptor effects would be a useful tool for both scientific and policy work in Canada. A potential platform for an IAM could be Regional Analysis by Intelligent Systems on a Microcomputer (RAISON), a PC-based expert system developed at the National Water Research Institute. Isaac Wong of NWRI demonstrated a version of RAISON at the workshop. As Jeffries (p.91) pointed out, an IAM such as RAISON which incorporates the results of ADOM will be used in the 1996 Assessment to help formulate a post-2000 strategy for regional acidification.

b) The present situation with respect to policy

i) International

Hedley (p.90) described various national and international policy activities. Beginning with the awareness of transboundary atmospheric transport and regional acidification that began with the 1972 Stockholm Conference, Canada has taken part in European program, begun by the OECD and taken over by the UN-ECE, under

Workshop on Atmospheric Issues in Atlantic Canada

which the Convention on Long-Range Transboundary Air Pollution was signed in 1979. Under this convention, there have been protocols in 1985 and in 1994 for reducing sulphur emissions, in 1988 for reducing NO_x emission, and in 1991 for controlling volatile organic compounds (VOCs).

ii) North America

In North America, Canada signed a Memorandum of Intent with the U.S. in 1980 to collaborate in a joint program of research and to work towards a bilateral emission control policy. In 1985 the seven easternmost provinces of Canada signed an agreement to reduce SO₂ emissions by 50% from 1980 values, with the reduction distributed among provinces to minimize cost and reduce acidic deposition in sensitive receptor regions.

In November 1994 the Canadian ministers of environment and energy agreed to collectively develop a National Strategy on Acid Rain which would ensure that our international commitments are met past the year 2000. This National Strategy is being developed through task groups comprised of all stakeholders and will address the emission reductions required in both the U.S. and in Canada to mitigate the negative impacts on human health, aquatic and terrestrial ecosystems, and on visibility.

c) Workshop deliberations

It must be pointed out that the responses of the workgroups that are listed in the remainder of Sections 4 to 6 are not listed in order of priority with respect to one another. They are, however, considered to be of greater priority than other environmental issues that were discussed and not listed below.

Question 1: What aspects of regional acidification are of the greatest importance in the Atlantic Region?

1. The health aspects of sulphate aerosols, in particular, the interaction of aerosols with oxidants in Saint John, New Brunswick. *This is a common issue with low-level oxidants. Although elevated levels of sulphates may be as much due to local emissions as to transboundary transport, the potential health effects of aerosol sulphates, in conjunction with frequent occurrences of low-level oxidants, are of concern.*

2. Acidic fog along the Atlantic Coast including the Bay of Fundy. *It was pointed out in the afternoon work group discussion that aerosol sulphates could combine with the fog that is found frequently over Atlantic coastal areas to form acidic fog. If these were inhaled, especially in conjunction with elevated concentrations of low-level oxidants, human health could be adversely affected.*

3. The joint effect of acidic deposition and increased UV-B radiation in brown (organic) lakes. *Acidification of these lakes could allow solar radiation, including UV-B, to penetrate to greater depths and have more adverse effects upon aquatic biota.*

4. The loss of aquatic habitat for species such as salmon. *As will be noted in Point 5 below, acidic deposition continues to be above critical loads for most of this region. Furthermore, the acidity of the water may be affected not only by the rate of acidic deposition but by variations in water temperature brought about by climatic change.*

5. The fact that the presently planned reductions in acidifying emissions will not bring acidic deposition within critical loads in the Atlantic Region. *The emission reductions that were initiated in 1985 in Canada used a target load of 20 kg sulphate per hectare per year. The critical load for much of the region is less than 8 kg/ha/yr and is being surpassed in most of the region, except for Labrador.*

Question 2: What are the results, in terms of a) improvements of our understanding of the environment, and b) changes in the environment, that we would like to see from our efforts in the next five to ten years?

1. Improved understanding of interactions between acidifying pollution and other issues such as oxidants. *The atmospheric chemistry of acidifying pollutants and oxidants is inextricably intertwined and needs to be taken account of in modelling.*

2. Improved understanding of any effects of sulphate aerosols and oxidants on health in an urban area such as Saint John. *There are synergistic effects of these two pollutants which are not known in Saint John.*

3. Improved understanding of the mechanisms between acidic deposition (including sulphates and nitrates) and aquatic acidification, including brown waters. *Much of the work has thus far been done on clear freshwaters.*

4. Continued long term records of acidic deposition, water quality and populations of aquatic species to monitor the effects of continued deposition and future changes in emissions. *Because of both long and short-term variations in both meteorological and aquatic variables, it is necessary to have long-term records of good quality to detect trends in a statistically significant way.*

5. Continued reductions of acidic deposition in the Atlantic Region to values that approach critical loads.

Question 3: What activities are needed to achieve these results?

1. An intensive study of the health effects of urban air quality in Saint John. *This should combine air quality data with epidemiological information.*

2. Development of Integrated Assessment Models (IAMs) that take into account time-dependency (chronic and episodic effects), linkages among various pollutants including sulphate and nitrate and changes in UV-B radiation. *These models should be based as much as possible upon regional studies.*

3. Maintenance of existing long term atmospheric and aquatic monitoring, and periodic re-evaluation of regional status. *This will require a joint effort by the federal and provincial governments, and by non-governmental bodies such as universities and private industry.*

4. A more relevant critical load assessment of critical loads for brown waters. *This could produce critical loads that are more suited to the Atlantic Region and thereby assist in developing more effective emission control strategies.*

5. Development of emission strategies within and outside the Region to reduce acidifying emissions. *Because much of the deposition in the Atlantic Region comes from emissions outside of the region, such strategies would probably have to encompass the Sulphur Oxide Management Area (SOMA). These strategies could include technological measures as well as economic instruments such as emission trading.*

5. Low-level Oxidants

a) The present situation with respect to science

i) Observed concentrations

Elevated concentrations of oxidants can occur on the local, regional and global scales. The presence of tropospheric oxidants at a given site may be due to 1) production from locally emitted pre-cursors, 2) downward intrusion from the stratosphere and 3) horizontal advection from upwind source areas (M. Lusi). While urban concentrations of oxidants have decreased somewhat since 1985 (possibly due to decreases in automobile emissions), there has been no significant change in regional concentrations. The Atlantic Region lies at the edge of a large area in the northeastern United States and southeastern Canada which experiences episodes of high concentrations of tropospheric oxidants (T. Dann). Although the Atlantic Region has fewer occurrences of elevated ozone (greater than the Canadian 1-hour objective of 82 ppb) than southern Ontario and Québec, it has more than Vancouver and, in some years, more than Montréal.

Beauchamp *et al* (p.87) examined an episode of elevated ozone and carbon monoxide concentrations at Kejimijuk NS in August 1993 and found that it occurred with a modest southwesterly flow, warm temperatures and clear skies in the warm sector in advance of an approaching cold front. Surface (1000 mb) back-trajectories indicated transport from the Boston-New York corridor, while higher level (925 and 850 mb) back-trajectories indicated transport more continental in scale. Tordon *et al* (p.99) found that, in 81% of the exceedances of the Canadian 82 ppb objective at 13 ground-level monitoring sites in the Maritimes, 1000 mb back-trajectories indicated transport from the northeastern United States, while 50% of back trajectories near the top of the mixed boundary layer indicated transport from the Great Lakes and Windsor-Québec corridor. Tordon *et al* also found that some exceedances occurred at night when locally-produced ozone should be at a minimum, further indication of long-range transport from outside of the region.

Ozone formation is due to precursors, i.e., oxides of nitrogen and volatile organic compounds (VOCs), reacting photochemically in the presence of sunlight (Dann *et al*, p.89). While oxides of nitrogen are mainly anthropogenic, VOCs can be both anthropogenic and naturally produced.

Workshop on Atmospheric Issues in Atlantic Canada

It is possible for ozone plumes to be transported long distances, including trajectories over water, although Cox *et al* (p.88) reported that ozone was depleted during passage over vegetated areas of the Lepreau Peninsula in New Brunswick.

M. Lusi reported on a major study on oxidants, the North American Research Strategy for Tropospheric Ozone (NARSTO). In the summer of 1995, NARSTO-Northeast took place in which instrumented aircraft followed the oxidant plume up the Atlantic seaboard. One purpose was to provide data that would improve our modelling capability. Canada has recently agreed to take part in NARSTO. Work in NARSTO in the summer of 1996 will focus on the Atlantic Region and Quebec. A workshop will be held in January or early February 1996 to invite proposals from potential contributors.

ii) Modelling

Shepherd and Olivotto (p.97) listed several oxidant models that are being developed for three regions of Canada: the Lower Fraser Valley of British Columbia; the Windsor-Québec City corridor, and the Southern Atlantic Region. The models typically underpredict ozone maxima by 5 to 8 ppb, while RMS errors are of the order of 20 to 25 ppb, similar to the uncertainty in observed ozone concentrations. The modelling results indicate that the long-range transport of NO_x, VOCs and ozone can be significant in eastern Canada.

iii) Effects on vegetation

High concentrations of oxidants can affect vegetation, human beings, and material. Vegetative effects have been most obvious in Ontario where the damage to crops from ozone is estimated at from 16 to 70 million dollars per year (R. Pearson). The Canadian objective of 82 ppb is based upon protecting tobacco plants from the effects of ozone. As outlined by R. Pearson, vegetative effects include pitting and flecking of tobacco leaves, and bronzing of the undersides of potato leaves.

Pearson (p.94) reported on the work of the Vegetation Objective Working Group (VOWG) under the NO_x/VOC Management Plan (to be described in the following section). Prior to the establishment of the VOWG, another U.S.-Canada working group concluded that the proposed 7-hour, June-August growing season mean for ozone of 32 ppb was inappropriate as a Canadian air quality objective and that a different, biologically-based measure of exposure was needed. It was also concluded that the 82 ppb 1-hour objective was reasonable for the purposes of the NO_x/VOC Management Plan, although it might not protect some sensitive plants or ecosystems. *This working group also concluded that the air quality databases for ozone, NO_x and VOCs in agricultural, forest and natural ecosystems at risk were woefully inadequate.*

However, a workshop in 1991 sponsored by the Canadian Institute for Research in Atmospheric Chemistry (CIRAC) concluded that:

- the current 1-hour objective of 82 ppb was not scientifically defensible and does not provide protection for known sensitive crop species
- there can be a single, scientifically defensible national ambient air quality objective for ozone but it would have to take into account the differing climate in various regions of Canada, the differing patterns of ozone exposure, the duration of the growing season in the region, and the sensitivities of the regional crops.

iv) Effects upon health

D. Stieb (p.98) reported that there was a wealth of studies on the effects of ozone on animal and human health. The effects can be due to both chronic (long term) and episodic exposure. Chronic exposure of animals (up to 1 ppm ozone for up to 18 months) showed a thickening of lung tissue where the oxygen transfer takes place to the blood, inflammation, and changes in cell type. Human studies in exposure chambers showed decreases in lung function, coughing, respiratory tract inflammation, and some evidence of interaction with allergens. There was some evidence that asthmatics became more sensitive during periods of elevated ozone concentrations.

Workshop on Atmospheric Issues in Atlantic Canada

Human field studies were often done in summer camps where the children were outside and active a considerable fraction of the time. Such studies also involved on-site monitoring of air concentrations and ambient air quality. There was evidence of lung function decreasing significantly with increasing ozone concentrations, although it was often difficult to distinguish between the effects of ozone and other air pollutants.

Stieb also described administrative studies which made use of death, hospital and school attendance records. Difficulties include the fact that the records were collected primarily for other purposes, and the abundance of confounding factors. For example, hospital admissions for respiratory complaints peak in January, whereas ozone concentrations are often a maximum in the summertime. Nevertheless, one time series study of hospital emergency department visits showed a 30-40% increase when ozone concentrations were greater than 60 ppb. Studies in Ontario indicated significant health effects with concentrations as low as 20 to 30 ppb. Cross-sectional studies which compared people in similar communities except for differing ozone concentrations indicated that ozone might aggravate existing diseases rather than initiate new ones.

According to Stieb, unanswered questions with respect to health effects were:

- the relative importance of micro- versus macro-effects (cellular versus lungs, for example)
- which part of the population is more susceptible, and why
- the effects of long-term exposure
- the effects of ozone relative to other stresses
- the possibility of adaptive measures (there is some evidence in Los Angeles that people do adapt to a certain degree to repeated exposures. However, there is at present no "safe" level that can be set.)

b) The present situation with respect to policy

i) International

Canada has taken part in several national and international endeavours to control the formation of tropospheric ozone (Hedley, p.90). Under the United Nations Economic Commission for Europe Convention on Long-Range Transboundary Air Pollution, Canada has signed two protocols related to ozone precursors: the protocol stabilizing NO_x to 1987 levels by 1994, signed in Sophia in 1988; and a protocol committed to reducing emissions of VOCs, signed in Geneva in 1991. (Canada has yet to ratify the VOC protocol, however.) The U.S. and Canada signed an Air Quality Agreement in 1991 which targetted emissions of both SO_x and NO_x. For example, the agreement called for a 100,000 ton reduction in NO₂ emissions from stationary sources in Canada. The U.S. standard for ozone is 120 ppb; however attainment of this standard in the U.S. will not bring concentrations in Canada below the objective of 82 ppb (T. Dann). Dann also reported that the U.S. program has been hampered by uncertainties in emission estimates for both anthropogenic and biogenic VOCs, the non-linearity of response of ozone concentrations to changes in emissions of NO_x and VOCs, lack of quality in regional measurements of ozone and its precursors.

ii) National

Within Canada, Phase I of the The Management Plan for Nitrogen Oxides and Volatile Organic Compounds, Phase I, accepted by the federal and provincial ministers in 1991, outlines preventative and remedial emission reduction measures with the intent of resolving Canada's low-level ozone problem by the year 2005, i.e., a consistent attainment of the 82 ppb objective. Phase II of the Plan will have four separate components:

- a national plan
- a plan for the Ontario part of the Windsor-Québec corridor
- a plan for the Québec part of the Windsor-Québec corridor
- a plan for the Lower Fraser Valley in British Columbia.

The national plan is expected to deal with the ozone situation in the southern Atlantic Region. T. Dann reported that, while urban NO_x concentrations have decreased during the past two decades due to controls on automobile emissions, there has been little or no decrease in VOC concentrations, and ozone concentrations have shown substantial year-to-year variability. When meteorological variability is removed from the analysis, many sites actually showed an increase in concentrations.

Several speakers (K. Hedley, T. Dann, D. Marquis) emphasized the point that tropospheric ozone must be dealt with on a regional basis - programs on an urban scale or within a single province will not deal with the issue.

c) Workshop deliberations

Question 1: What aspects of low-level oxidants are of greatest importance in the Atlantic Region?

1. The relative importance of oxidants imported from other regions of eastern North America and those from locally emitted precursors. *It is not known if the frequent episodes of elevated concentrations of low-level oxidants that are experienced in the Atlantic Region are due to advection of air masses from the eastern United States and central Canada, or emissions from local industries, or both.*

2. The combined effects of oxidants and sulphate aerosols on human health, especially in urban areas such as Saint John. *This is an issue in common with regional acidification. (See Section 4(c))*

3. The effects of oxidants, combined with climatic change, on forest species (including biodiversity) in the Atlantic Region. *Because forests are such an important resource in the region, it is important to know the effects of low-level oxidants on them, in isolation and in combination with other stresses such as climatic change. Will the species mix shift to less economically valuable species?*

4. We do not have a very good ability to assess, over an extended period into the future, changes in air quality and receptors due to changes in oxidant precursors. *The concentrations of oxidants depend in a non-linear fashion upon combinations of emissions of precursors; reducing emissions of one precursor may not have an appreciable effect, and may even be counter-productive.*

Question 2: What are the required results, in terms of a) improvements of our understanding of the environment, and b) changes in the environment, that we would like to see from our efforts in the next five to ten years?

1. An improved knowledge of the behaviour of locally produced precursors in an aged air mass, and the effects of the maritime boundary layer upon formation and dispersion. *Air masses arrive in the region after having travelled several hundred kilometres from distant source regions; much of the trajectory has been over cold water surfaces where a stable boundary layer has been formed, hindering vertical dispersion. We want to know how locally-produced precursors are dispersed into this air mass and how they react with the precursors from distant source regions.*

2. Improved knowledge of the combined effects upon human health of oxidants and sulphate aerosols. *Reducing concentrations of sulphate aerosols may not reduce stress on human health as much as expected if concentrations of oxidants are also not reduced, and vice versa.*

3. An assessment of the effects of low-level oxidants, over a long time spanning the past and the future, on air quality and receptors. *Both air quality (regional and urban) and epidemiological data will be needed to see if future control programs for oxidant precursors will have a beneficial effect.*

Question 3: What activities are needed to achieve these results?

1. Development of integrated oxidant models capable of simulating long-range transport, formation from locally emitted precursors, transport and dispersion within the maritime boundary layer, and effects upon receptors. *Models that have been already developed should be modified to simulate the special atmospheric dispersion conditions within the marine boundary layer. They should also be able to incorporate the effects of climatic change upon sunlight and temperature which are important factors in the atmospheric chemistry. These models will hopefully be able to estimate the effects of proposed reductions in emissions of oxidant precursors.*

2. Canadian scientists should submit study proposals for and take part in the 1996 North American Research Strategy for Tropospheric Ozone (NARSTO) field study in Québec and the Atlantic Region to obtain data to improve model predictions. *It is important that our scientists remain involved and in contact with others (including U.S. scientists) working in the field.*

3. Maintenance of long-term quantitative monitoring of air quality and forest species. *Only a long-term, relatively continuous time series of these data will enable us to determine whether or not changes in emissions of oxidant precursors have an effect upon air quality and forests. A two-tier databank should be established: 1) data that can be accessed quickly by the public and 2) quality-assured data for research purposes. The recent recommendations from the NO_x/VOC Science Program for collecting data on NO_x and VOCs should be implemented. This activity should be incorporated as much as possible into the Environmental Monitoring and Assessment Network (EMAN).*

4. Establishment of improved dose-response relationships and critical levels for the effects of low-level oxidants on both human and terrestrial plants, including forests. *These relationships need to be determined for conditions that exist in the Atlantic Region. These dose-response relationships could then be used to select sensitive indicators.*

5. Formation of partnerships among governments, academia, industry and the public. *Partnerships make good sense because of the current reduction of government budgets, and the fact that both the public and private sectors have a vested interest in maintaining healthy natural and human environments. An example of such a partnership was that of P. Arp (p.84) which was partially funded by the pulp and paper industry.*

6. Stratospheric Ozone Depletion

a) The present situation with respect to science

i) Ozone amounts

The stratospheric ozone layer, located between 10 and 30 km above the Earth's surface with a peak in O₃ concentration at about 20 km, contains a column of about 3.6 mm of O₃, if compressed to sea level pressure. Despite its thinness, this layer significantly absorbs solar radiation at ultraviolet-B (UV-B) wavelengths of about 280-320 nm which can harm both human and plant life. In his verbal presentation, D. Wardle described how chlorinated hydrocarbons, such as chlorofluorocarbons (CFCs) which are used by humans as aerosol propellants, solvents and refrigerants, are almost chemically inert (with lifetimes of 55-110 years) and can, after release at ground level, diffuse to the stratosphere and take part in the catalytic destruction of ozone. Wardle showed time series of total ozone in an atmospheric column at five Canadian stations which showed a decrease of about 5% from pre-1980 values. The greatest loss in ozone in mid-latitudes occurs in the springtime when radiation from the sun initiates the destructive reactions. The atmospheric concentration of CFCs has been increasing but the rate of increase has been slowing due to the ban of CFCs (see next section).

With respect to regional monitoring efforts, Beattie and Keddy (p.102) reported on the results of monitoring ozone in the total atmospheric column at Goose Bay NF since 1962 (based on work by D. Jarasick of the Atmospheric Environment Service), and at Bedford NS since 1992. At Goose Bay, there was a statistically significant decrease (at the 95% confidence level) of 0.50 +/- 0.27% for the period 1980-1984, even after excluding 1993 which may have been affected by aerosols from the eruption of Mount Pinatubo. (Since ozone destruction occurs on sulphate aerosols injected into the stratosphere by major volcanic eruptions, the large depletion observed during 1993 in Canada, and indeed on a global basis, was quantitatively consistent with the occurrence of sulphate aerosols in the stratosphere from the 1991 eruption of Mount Pinatubo.)

Because there were no long-term measurements at Bedford, it was necessary to use a proxy ozone climatology based upon observations from satellites and long-term ground stations to represent pre-1980 conditions. At Bedford in 1993, large negative departures from normal conditions were experienced, especially in the winter and spring months, with some daily departures of more than 30% below normal. Monthly average depletions of 12 to 15% occurred from January through May. Total column ozone averaged about 7% below normal for the year.

ii) Terrestrial effects

With respect to the effects on terrestrial plants of increased UV-B radiation due to the depletion of the stratospheric ozone layer, there was a verbal presentation by Y. Papadopoulos and a group of posters by various researchers. Papadopoulos' verbal presentation (see also Papadopoulos *et al*, p.118) gave an overview of the results of current research in the Atlantic Region on the sensitivity of various plant species to increased UV-B radiation, as well as future research needs. Papadopoulos stated that a literature survey showed that research on the sensitivity of plants to increased UV-B involved a total of about 300 species (practically all from temperate latitudes) at greater than ambient levels of UV-B radiation. A wide variety of sensitivity to increased UV-B was reported. Very little work has been done on tropical species, i.e., species common in developing regions. There is no doubt however, that some species of plants can be adversely affected by increased UV-B radiation. These adverse effects include DNA lesions, reduction of photosynthesis, and photomorphogenetic responses (alteration of plant structure). Papadopoulos reported that, although there are adverse effects, some species showed a definite resistance to increased UV-B and an ability to adapt, qualities which potentially could be exploited by plant breeders.

The various poster presentations on the effects of increased UV-B radiation on plants described work at various research establishments in the Atlantic Region. Papadopoulos *et al* (p.117) described work on four legume and four grass species during two growing seasons (1993 and 1994). Two sets of plants were examined - one in which UV-B radiation was excluded by polyester screens. (The system of screening out UV-B radiation was described by Gordon *et al* (p.108). Papadopoulos *et al* reported that, in 1993, herbage yield of both grasses and legumes was

lower when ambient UV-B radiation was excluded, but this response was statistically significant only in the first growth period when the UV-B levels were highest. The effect of current levels of UV-B radiation on herbage yield vary within and among the species that were evaluated. Similar results were obtained in 1994 with two important exceptions during the first growth period: 1) the interaction with UV-B levels did not vary significantly with species, and 2) UV-B radiation had no effect on the herbage yield of grass species. It is clear that further field studies are needed to clarify the resistance of current perennial forage cultivars to the cumulative exposure to ambient UV-B radiation during succeeding production years.

Bélanger *et al* (p.104) found that removing UV-B radiation from timothy grass (using the system described by Gordon *et al*) increased leaf elongation rate and the number of tillers per plant. However, they stressed that these results are preliminary and need further testing. Bush *et al* (p.106) examined the effect of reduced UV-B radiation on four broccoli cultivars during 1993 and 1994. There were no consistent trends between treatments as some cultivars appeared to show a consistent response to level of UV-B while others did not. The differences between the crop years appears to be due to stresses other than UV-B that had an effect of flavonoid synthesis as well as plant yield.

iii) Effects upon aquatic ecosystems

The factors to be considered in quantifying the effects of stratospheric ozone depletion on aquatic systems was discussed in a verbal presentation by J. Cullen (see Cullen *et al*, p.107). He stressed that merely measuring the UV-B flux would not give us the potential effects of ozone depletion on the photosynthesis in a water column; this flux would have to be weighted by a "Radiation Amplification Factor (RAF)" which would take into consideration not only the spectral irradiance but also vertical extent of mixing, the UV-B attenuation coefficients in the water column, the uninhibited photosynthesis, and the biological sensitivity (on a wavelength basis) to changes in UV-B radiation. Defining these factors is difficult enough for a single species, and much more so for a population.

One poster presentation (Moroz *et al*, p.116) dealt with the effect of UV-B radiation on the movement of one freshwater diatom, *Nitzschia linearis*. The percentage of moving and non-moving cells was affected significantly by the presence or absence of UV-B radiation; the percentage of oscillating cells did not change significantly.

iv) Effects upon health

In a verbal presentation, Y. Deslauriers described the effects of UV-B radiation on the eyes and skin of humans. The main effects on human eyes would be photokeratitis of the cornea, photo-conjunctivitis of the "white" part of the eye, opacities, and cataracts. Effects on the human skin would be pre-vitamin D production, erythema and sunburn, tanning, suppression of the immune system, photo-allergies and photo-toxicity, accelerated aging, and skin cancer, including melanoma, the last which is considered to be lethal. Non-melanomic skin cancer has been increasing in the fast few years (it is presently at 60,000 per year); although it is non-fatal it is a major and preventable burden on health care systems. There are good statistics on melanoma as it is perceived as being fatal; it is estimated that there will be about 315 cases in 1995 in the eastern provinces with 50 to 60 deaths. Melanoma may not be directly caused by UV-B radiation but overexposure may increase the susceptibility of certain individuals. Deslauriers ended with the following advice:

- avoid over-exposure to the sun, especially in children
- tanning is *never* safe, even with tanning equipment
- sunscreens protect only against sunburn
- ozone depletion is likely to increase the incidence of skin cancer, cataracts, and suppression of the immune system in future generations.

b) The present situation with respect to policy

i) International

J. Kozak (p.109) in his verbal presentation described the international and national programmes to limit the emissions of ozone-depleting substances (ODS). After the first realization in 1974 that substances such as CFCs might lead to the destruction of the stratospheric ozone layer, the United Nations Environment Programme in 1977 began assessing the scientific information and its implications for policy. International negotiations led to the signing of the Vienna Convention in 1985 and the Montréal Protocol in 1987. These international agreements intend to protect the ozone layer by reducing the release of ODS into the atmosphere, with the ultimate goal of eliminating ODS consumption world-wide. Two amendments to the Protocol - the London Amendment (1990) and the Copenhagen Amendment (1992), accelerated the phase out measures for ODS and added HCFCs, methyl bromide and HBFCs.

ii) National

Canada has been and continues to be very supportive and proactive regarding the protection of the ozone layer. The federal government has put in place both regulatory and non-regulatory initiatives to reduce the release of ozone-depleting substances to the atmosphere. Beginning in 1980, the federal government started to control CFCs by banning their use in aerosol propellants. By 1993, the Canadian programs, including provincial actions, resulted in a 77% reduction of Canadian annual consumption of CFCs from 1986, the base year of the Montreal Protocol.

Canada is strengthening its ODS programs to accelerate reductions in ODS consumption and releases. It is intended to phase out the use of halons by the year 1994, CFCs by 1996, and HCFs by 2010. Non-regulatory initiatives include a National Action Plan involving:

- recovery of CFCs from refrigerators
- recycling and destruction of ODS
- use non-ozone destroying substitutes for ODS.

Workshop on Atmospheric Issues in Atlantic Canada

Regional measures include the implementation of national ODS regulations, promotion and education of the need for reducing emissions of ODS, monitoring of UVB levels (see below), harmonization of federal programmes with those of the provinces and municipalities, and provision of technical advice and feedback to Environment Canada headquarters.

In addition to the regional measures to reduce and eliminate ODS, a program to educate and inform the public was described in a poster presentation by Beattie *et al* (p.103). The Canadian "UV Index" TM was launched in the spring of 1992. In so doing, Canada became the first country to provide a daily forecast program of UV radiation levels. The daily forecast is based on the angle of the sun at solar noon, the forecast amount of ozone overhead and the predicted amount of cloud over the site in question. The chief goal of the forecast program is to provide a means for the public to make daily decisions about the appropriate levels of sun protection. Therefore, general advice on sun exposure is provided as part of the program. Specific sun protection actions will be recommended when they become available from the health agencies.

Atlantic Canada receives less ultraviolet radiation than more southerly locations. Nevertheless, in 1993 at Bedford, total column ozone averaged 7% below normal for the year (see Beattie and Keddy, p.102) and UV measurements well above normal were associated with periods of lower than normal ozone thickness that occurred during the first two-thirds of the year. The highest UV Index measurement in 1993 was 9.7 on July 12, which was about 30% above normal for that date. The column of ozone above Bedford that day was 12% below normal.

c) Workshop deliberations

Question 1: What aspects of ozone depletion are of greatest importance in the Atlantic Region?

1. Past and future changes in the incoming flux of UV-B radiation in the Atlantic Region. Few long-term measurements are available for the past, and there will be a need, considering the current efforts to reduce and eliminate emissions of ozone-depleting substances, to monitor the effects these efforts on the UV-B radiation flux.

2. Effects of changes in UV-B radiation on forest, aquatic and agricultural ecosystems in the Atlantic Region. As reported at the workshop, some work has been done on agricultural crops, but more needs to be done on both agricultural and forest crops, and aquatic ecosystems.

3. Effects on human beings from changes in UV-B radiation. Much is known generally about effects of UV-B radiation on the skin and the eyes, but there is little or no information specific to the Atlantic Region.

Question 2: What are the required results, in terms of a) improvements of our understanding of the environment, and b) changes in the environment, that we would like to see from our efforts in the next five to ten years?

1. Improved, continuous time series of UV-B radiation measurements in the Region with adequate spatial coverage. *This information would not only be needed to monitor the effects of programs to reduce emissions of ozone-depleting substances, but would also be needed to continue the implementation of the Canadian "UV Index"™.*

2. Increased understanding and quantification of the effect of UV-B radiation on forest, aquatic and agricultural ecosystems, including linkages to other issues such as regional acidification and climatic change. *This information would be useful in assessing the potential economic damage to the region's resources due to increased UV-B radiation in the future.*

3. Better dose-response relationships and indicators of effects of UV-B radiation that are specific to the Atlantic Region. *Little regional information is available, especially for forest species. This information would be needed to predict the possible changes in damage due to changes (positive and negative) in UV-B radiation.*

4. Minimization of biological effects through the development of crops that are more UV-B resistant. *It is likely, because of the long residence time of ozone-depleting substances in the atmosphere, that UV-B radiation may continue to increase for several decades. For that reason, adaptive measures in terms of crops will be necessary.*

5. Minimization of the effects of UV-B radiation upon humans. *Apart from measures to reduce emissions of ozone-depleting substances, adaptive measures to minimize exposure to UV-B radiation will be needed.*

Question 3: What activities are needed to achieve these results?

1. Monitoring of UV-B radiation by ground stations and satellites, if possible through collaboration with the Environmental Monitoring and Assessment Network (EMAN). *Monitoring is needed for a variety of reasons: model development and testing, research on effects on humans and plants, and public information. It may be more cost-effective to do this monitoring in collaboration with other programs such as EMAN.*

2. Field studies of effects of increased UV-B radiation on ecosystems at existing sites such as Kejimikujik. *These studies would make use of the measurements discussed in Point 1 above and would follow as much as possible an ecosystem approach which would look at other atmospheric stresses as well, for example, regional acidification and climatic change.*

3. Selection of UV-B resistant crops at agricultural research stations. *The work on examining UV-B resistant crops that was reported at the workshop should continue in order to provide support to our future adaptive measures.*

4. Promotion of sun-safe behaviour through publicization of the Canadian UV IndexTM and public education about how to minimize exposure to UV-B radiation.

5. Support of national programs on eliminating and minimization of the use of Ozone Depleting Substances (ODSs). *Although national and international effort is needed to address the issue of stratospheric ozone depletion, such efforts need commitment on the regional, municipal and personal level.*

7. Hazardous Air Pollutants

a) The present situation with respect to science

As described by Kozak in his verbal presentation (p.109), the Organisation for Economic Cooperation and Development (OECD) describes hazardous air pollutants (HAPs) as contaminants in the air which may pose a significant risk to plant or animal (including human) life. HAPs may be in gaseous, liquid or particulate form; those subject to transboundary atmospheric transport are of special concern. Most of the effort thus far has concentrated on persistent organic pollutants such as pesticides and polychlorinated biphenyls (PCBs), and heavy metals such as mercury.

i) Atmospheric sampling

In Canada, much of the scientific effort has been concerned with the Great Lakes and the Arctic but there were several verbal and poster presentations at the workshop dealing with research in the Atlantic Region. Tordon *et al* (p.119) described atmospheric sampling of mercury at Kejimikujik National Park in southwestern Nova Scotia. They intend to use analyses of back-trajectories as well as wind speed and direction to estimate the source regions of elevated concentrations.

Brun (p.105) described the monitoring of HAPs in wet precipitation samples at four sites in the region; analyses were carried out for organochlorine pesticides, triazine herbicides, chlorinated phenols, polychlorinated biphenyls (PCBs), chlorinated benzenes and polyaromatic hydrocarbons (PAHs). Some of the results are as follows:

1) The compounds most commonly found included the pesticide lindane (γ -HCH) and its decomposition product α -HCH, fluoranthene, and PCBs. Statistical analysis indicates a significant decrease in concentration for γ -HCH and α -HCH after 1983. Seasonal patterns were observed with maximum concentrations/loadings occurring during the spring and fall.

2) Fluoranthene and other PAHs were shown to follow seasonal patterns, with increasing concentrations during the colder months of the year (December to April). Spatial influences were also observed, suggesting both localized and long-range atmospheric source inputs.

3) Abnormally high annual mean concentrations of PCBs ranging between non-detectable levels and $0.22 \mu\text{g/L}$ were measured during the 1981-1986 period at the PEI site. Spatial variations for PCBs in the Atlantic Region were significant and attributed in part to local source inputs. Seasonal patterns similar to the PAHs were also observed. Concentrations dropped to non-detectable levels after 1984 at all sites with the exception of a few sporadic observations.

W. Strachan described in his verbal presentation the monitoring of HAPs (lead, mercury, cadmium, arsenic, HCB, Mirex, Aldrin, HCHs and DDT) in precipitation samples in a network across Canada. It has been found, for example, that 6% of the input of PCBs to Lake Ontario is via the atmosphere; for Lake Superior the atmospheric contribution is 90%. However, 53% of the *output* from Lake Ontario is via the atmosphere; for Lake Superior it is 86%. In contrast, there is no output of lead from the Great Lakes via the atmosphere but the atmosphere provides an important input. This means that the atmosphere is an important pathway for hazardous pollutants. Mercury, because it is volatile, undergoes a "grasshopper effect" in which there is a net poleward migration because condensation will overcome re-volatilization in the colder temperatures found at higher latitudes.

Strachan stated that concentrations of alpha-HCH and t-endosulphane were high at Kouchibouguac NB in 1991. It is unclear if these concentrations are due to local or distant sources. Concentrations of HAPs in precipitation tend to decrease from west to east in Canada, but deposition fluxes can be significant on both Pacific and Atlantic coasts because of the high annual precipitation. Finally, Strachan made a plea for standardization of collection and handling techniques for HAPs in precipitation.

Rutherford *et al* (p.119) examined mercury deposition in peat cores from five raised bogs in New Brunswick, Nova Scotia and Prince Edward Island. Results were highly variable with no common pattern of atmospheric mercury deposition exhibited by all bogs. Three of the bogs showed a general trend of increasing mercury deposition from the mid-1800s (0.018 to $0.124 \mu\text{g/g}$ dry wt.) until the late 1970s and early 1980s (0.083 to $0.157 \mu\text{g/g}$), when mean mercury concentrations in peat dropped off markedly approaching pre-1850's values (0.035 to $0.051 \mu\text{g/g}$ dry wt.). Variability in the data may be the result of sampling methods, regional atmospheric deposition patterns or mobility of mercury within the peat profile.

ii) Bioaccumulation

G. Harding gave a verbal presentation on the documentation of the bioaccumulation of PCBs in the entire marine food chain in St. George's Bay in the Gulf of St. Lawrence, starting with the input by precipitation and ending with fish. Rain had the same concentration of PCBs as the seawater (of the order of parts per trillion), while snow had much higher concentrations, although Harding admitted that the snow collection device was serviced infrequently. Because there is no significant river flowing into St. George's Bay, it was believed that the major input of PCBs was via precipitation. PCB concentrations in plankton was several times higher (of the order of parts per billion) than in the seawater; they were greatest in the springtime and in the mid-sized plankton. There was no correlation between PCB concentrations in rain and in plankton. In turn, concentrations in fish were two orders of magnitude greater than those in plankton. There was no difference in concentrations between male and female fish, but females were transferring PCBs to their eggs, albeit at lower concentrations. Harding estimated that, despite the bioaccumulation, 98% of the mass of PCBs was in the seawater, and only 2% in the biomass. Therefore, if there is no significant flux of PCBs from the seawater, the possibility for continued bioaccumulation remains.

b) The present situation with respect to policy

i) International

Two verbal presentations reviewed the situation with respect to control policies: first by J. Kozak (p.109) for international policy and, second, by W. Ernst for policy within Canada. Kozak stated that the Executive Body of the United Nations Economic Commission for Europe (UNECE) was given the mandate to proceed with initiatives with respect to hazardous air pollutants and is initiating discussions in Geneva in February 1996 on the development of protocols for heavy Metals and persistent Organic Pollutants (POPs) under its Convention on Long-Range Transboundary Air Pollution. The protocols will focus on 16 POPs; Canada is leading the negotiations.

Workshop on Atmospheric Issues in Atlantic Canada

In May 1995, the United Nations Environment Programme Governing Council decided that a global strategy for managing POPs should be prepared by early 1996. As a first step, profiles have been developed for 12 POPs, in collaboration with the World Health Organization, and were presented to the Washington Conference on Land-Based Sources of Marine Pollution in late October 1995. At the Washington Conference, it was agreed that a global legally binding instrument should be developed for the management of POPs. The UNEP POPs list was adopted as an action list on a global scale. There was, however, no agreement on the need to develop a global strategy for heavy metals. Nevertheless, there was a commitment by all parties to prepare national action plans for POPs and heavy metals by 1998.

In North America, Canada, the United States and Mexico, under the auspices of the North American Free trade Agreement (NAFTA), are expected to sign a Resolution on the Safe Management of Chemicals. The NAFTA Commission for the Environment has selected an initial list of persistent toxic substances which initially is the same as the UNEP POPs list. In addition, Canada and the US are drafting a strategy under Annex 15 of the Great Lakes Water Quality Agreement to accelerate measures to reduce the input of persistent toxic substances to the Great Lakes.

In February 1995, Canada and the United States agreed that a strategy would be developed by February 1996 to address the most persistent toxic substances in the Great Lakes environment. A draft strategy was developed in August 1995 which will accelerate action under Annex 15 of the Great Lakes Water Quality Agreement. Reductions in the Great Lakes Basin will be addressed under the current Lakeside Management Plans, whereas this strategy will focus on sources outside the Great Lakes Basin in Canada and the continental United States.

ii) National

W. Ernst (p.107) gave a detailed description of policy measures for hazardous air pollutants that have been taken within the Canada Environmental Protection Act (CEPA). The management approach is two-pronged: 1) to examine substances that are presently used in Canada and which may have to be controlled and 2) to deal with potentially toxic substances that are new to Canada.

With respect to the first approach, a list of 23,000 substances in present use in Canada has been compiled and, from that list, the first Priority Substance List (PSL 1) comprising 44 substances has been segregated for further assessment. The Strategic Options Process (SOP) has been adopted as a consultative approach among the relevant stakeholders to define risk assessment and as a result 25 of these 44 substances have been declared toxic under the CEPA. The SOP/Issue Table process is a multistakeholder consultative process to prepare recommendations to the accountable federal Ministers on options to manage toxic substances. For example, an SOP/Issue Table is underway for the fossil fuel electric power generating sector.

A voluntary alternative to regulatory measures is the Accelerated reduction and Elimination of Toxic Substances Programme. Industries can submit to the federal government action plans to reduce the use and emission of toxic substances. Thus far, 145 companies have submitted plans, and 14 substances have been identified as being of high priority.

Another provision under CEPA is the National Pollutant Release Inventory which has collected information on 178 substances since 1993. Its purpose is to identify priorities for control measures, to encourage voluntary control measures, and to track the amounts circulating in the environment. Some of the information required for the inventory is a projection of the mean 3-year release, the destination of the substance, and the location of the facility releasing the substance.

With respect to the second approach, there has been since July 1994 a requirement for a New Substance Notification under the CEPA. Those who wish to introduce a new substance into Canada must prove that it is not toxic. The approach is organized by class of substance, and expected quantities and nature of use. The maximum time allotted for assessment is six months after which use is approved or denied.

Finally, the Toxic Chemical Management Policy is an attempt to guide all federal policies with respect to hazardous pollutants. Those anthropogenic substances deemed to be persistent and bio-accumulating will be phased out. Others will be subject to life-cycle management.

c) Workshop deliberations

Question 1: What aspects of hazardous air pollutants are of greatest importance in the Atlantic Region?

1. Our lack of knowledge about hazardous air pollutants (HAPs) in the Atlantic Region, specifically:

- *emissions of HAPs in the region*
- *atmospheric concentrations of HAPs*
- *deposition from the atmosphere by dry processes and by precipitation*
- *relative importance of sources within and outside the Region*
- *penetration of HAPs into natural and human ecosystems, including local "hot spots"*

2. The importance in the Atlantic Region of mercury as a hazardous air pollutant is not well known. *Mercury is considered to be an emerging environmental issue. Environmental sampling is complicated by its ability to revolatilize into the atmosphere.*

Question 2: What are the required results, in terms of a) improvements of our understanding of the environment, and b) changes in the environment, would we like to see from our efforts in the next five to ten years?

1. An assessment of the relative importance in the Atlantic Region of airborne toxic pollutants, including mercury, in terms of emissions, concentrations, deposition and toxicity.

2. An assessment of the relative importance of sources of hazardous air pollutants within and outside of the Atlantic Region. *This is important to determine the importance of control measures within the Region.*

Question 3: What activities are needed to achieve these results?

1. Establishment of a team, horizontally integrated among federal and provincial government agencies and others, to:

- develop a definition for hazardous air pollutants (HAPs) relevant to the Atlantic Region*
- examine existing national and regional data on emissions, concentrations and deposition, toxicity, and presence of HAPs within ecosystems in the Region*
- select the HAP(s) of greatest concern in the Region*

2. As a test case, establish an ecosystem study for mercury, using if possible an existing site. *One possible site for such a study could be the EMAN site at Kejimikujik, Nova Scotia.*

8. Climatic Change

a) The present situation with respect to science

i) General

The concept that certain trace gases in the atmosphere could have a warming or "greenhouse" effect was first postulated by the Swedish scientist Arrhenius exactly a century ago. Indeed, the greenhouse effect brought about by naturally emitted gases, such as carbon dioxide and methane, alters the radiative balance in the atmosphere and raises its temperature to values that render Earth habitable to presently existing forms of life, including humankind. However, concern has mounted in the past two or three decades that human activities are leading to large emissions of greenhouse gases which include not only CO₂ and CH₄ but totally anthropogenic gases, such as chlorofluorocarbons (CFCs). Increases in the concentrations of these gases could cause the mean temperature of the atmosphere to increase, with possible deleterious effects upon sea level, the hydrological cycle and terrestrial, freshwater and marine biota. Much controversy remains as to the degree, extent and spatial distribution of these possible effects.

In her verbal presentation, P. Kertland discussed some of the general scientific aspects of climatic change, including the recent increase in greenhouse gas concentrations. Most of the estimated recent increase in radiative warming comes from CO₂, because of the huge amounts emitted by our combustion of fossil fuels. However, other gases such as methane and CFCs can have a more powerful warming effect on a mass basis. Kertland noted that, although the concentration of methane has doubled since 1900, the increase in atmospheric concentrations of CFCs has been tapering off recently, probably due to the implementation of the Montréal Protocol which was signed in 1987 and which required reductions of ozone depleting substances such as CFCs.

ii) Modelling

Because the effects of greenhouse gases are only just becoming evident, scientists use models to calculate the effects upon atmospheric temperature and precipitation patterns. Various types of models were reviewed in the verbal presentations of both P. Kertland and of G. Koshida (p.125). There are three basic types of models: equilibrium Global Climate Models (GCMs), transient GCMs and analogue models. Equilibrium GCMs assume an immediate doubling of atmospheric CO₂ concentrations from pre-industrial values and calculate the atmospheric temperature resulting from the new radiative balance in the atmosphere. Increases in the global mean temperature calculated by these models are typically 3.5 to 4°C for a doubling of CO₂ concentrations.

Because the concentrations of greenhouse gases are occurring gradually, a more realistic type of model is the transient GCM which, because of the dynamic nature of the problem, must take into consideration the coupling between the atmosphere and the ocean. As pointed out by Kertland, transient GCMs could take into consideration other factors such as the radiative effects of aerosols. Because transient GCMs account for thermal lags in the ocean-atmosphere system, the calculated global temperature increases calculated by these models for the year 2100 are less than those calculated by equilibrium GCMs - from 1.3 to 2.3°C. These models can calculate both the seasonal and geographic distribution of temperature and precipitation changes but it is acknowledged that the regional calculations of GCMs are very uncertain and have poor spatial resolution (G. Koshida stated that there are only about 20 GCM grid points in the Atlantic Region) The present inadequacies of the regional predictions of GCMs poses a severe restriction on those scientists concerned with the ecological effects on ecosystems whose characteristics may vary on a fine geographical scale.

Another approach to studying the effects of climatic change is through the use of analogues. Koshida stated that these analogues could be temporal or spatial in nature. Temporal analogues look at information from another era; for example, concentrations of atmospheric CO₂ could

be estimated from ice cores from glaciers, concurrent changes in atmospheric temperature could be estimated from the distribution of pollen in sediments. Spatial analogues would use present-day climate information from one region and apply it to another region, presumably one with similar characteristics but a different current climate.

ii) Observations

Has in fact the climate in the Atlantic Region been changing in the recent past? Koshida stated that GCMs estimated that, with a doubling of CO₂ concentrations, winter temperatures could increase by 4-9°C while summer temperatures could increase by 4-6°C. However, it was the consensus of several presenters at the workshop that temperatures in the Atlantic Region and other areas bordering the North Atlantic have exhibited periods of both warming and cooling; unlike other areas such as western Canada (G. Koshida) there has *not* been a steady warming trend in Atlantic Canada.

The poster of Pocklington and Morgan (p.128) examined annual mean surface air temperature records from around the northern North Atlantic, northwestern Europe, and eastern North America. In North America, Pocklington and Morgan found that decadal surface air temperature means show that in 15 out of 33 defined regions, the warmest decade of the century occurred before the 1980s. More regions show a decline in temperature of the same magnitude between the penultimate and the most recent 30-year mean. In Canada, the most recent decade was the warmest in the record - by only 0.1 deg.C - but the 1961-90 mean is cooler than the 1931-60 mean by approximately this same amount. In eastern Canada, a warming trend from the end of last century to the middle of this century has been followed by consistent cooling. This cooling was particularly noticeable over Baffin Island and along the coast of Labrador. Comparison with coastal stations around the periphery of the North Atlantic Ocean indicates that this cooling is part of a general northern North Atlantic temperature decrease.

Pocklington and Morgan concluded that any warming in Canada as a whole over the past 60 years has been marginal and the case for any general warming since 1885 rests upon the sparse pre-1930 record.

Jacobs and Banfield (p.124) found that surface air temperatures from northern Baffin Island to Newfoundland have been decreasing over the past three decades with an average trend of 0.02°C , due mainly to colder winters. They admit that, due to inter-annual variability, the statistical significance of their results using surface air temperatures is questionable. However, when they use subsurface ground temperatures which are highly correlated with surface air temperatures, the cooling trend is statistically significant. They contend that this cooling has been revealed in at least one GCM simulation and may be related to either a weakening of the thermohaline circulation in the North Atlantic or, more likely, changes in atmospheric circulation patterns due to an increase in the west-to-east gradient of the tropospheric thickness.

The poster of Knox *et al* (p.125) related surface temperature in eastern North America to the variability of the Canadian Polar Trough (CPT). Canada's east coast experienced a warm winter regime 1951-1960, followed by a cold regime from the early 1970s to the present. The trend and the interannual variability of winter mean temperature were found to be related to variability in the circulation of the CPT. For the summer season, this relationship was not so clear.

In one poster, Lewis and MacSwain (p.126) examined trends in the maximum, minimum temperatures and diurnal temperature range (DTR) at three long term stations in the Maritime Provinces - the Canadian Department of Agriculture Stations (CDA) at Charlottetown, Fredericton and Kentville with records back as far as 1911, and for a regional data set of eight climate stations for the period 1945-1990. On an annual basis, all three long term stations showed a decrease in the DTR caused by a greater increase in minimum temperatures than in maximum temperatures. On a seasonal basis, all three showed a marked increase in minimum temperature to have occurred in the winter months and all three showed their least increase in minimum temperatures during the fall.

For the regional data set Lewis and MacSwain found that the DTR decreased both annually and for all seasons. However, although minimum temperatures increased in all seasons except winter, a decrease in maximum temperatures contributed significantly to the decrease in the DTR.

Climatic change may involve not only changes in mean values but changes in temporal variability. In another poster Lewis and MacSwain (p.126) used a temperature-precipitation departure (TPD) index as an indicator of climate variability. Time series for two long-term records in Maritime Canada for the period 1911-1990 showed similarities in fluctuation and both show a marked increase in the magnitude of fluctuations since 1950. In a regional study of the Maritime Provinces, annual and seasonal time series for the period 1944-90 also indicated periods of high and low fluctuations. Lewis and MacSwain suggested that the index could be used as a tool in studies which attempt to correlate climate variability with forcing factors such as El-Nino Southern Oscillation (ENSO) events or major volcanic eruptions.

iii) Effects upon aquatic ecosystems

Climatic change may lead to physical, biological or chemical changes in ecosystems. T. Clair gave a verbal presentation with P. Dillon on the implications of climatic change on freshwaters and their associated biota. Although there have not yet been many changes in observed temperature and precipitation in the Atlantic Region resulting from increases in greenhouse gases (see above), GCMs are calculating temperature increases of several degrees C and changes in precipitation of +/- 20%. Such changes would have a significant effect upon evapotranspiration in river basins and, therefore, volume discharge. Changes in volume discharge could range from -39 to +59%. For example, a combination of reduced precipitation and warmer temperatures would lead to less water input to the basin, higher evapotranspiration, lower lake levels, alteration of fish spawning. Lower water levels could incur infrastructure costs such as the extension of water supply intakes and stormwater outfalls, increased dredging, and the relocation and re-building of marinas and beaches.

The poster of Brimley (p.122) described the establishment of a network of watersheds in Atlantic Canada involving long-term hydrometric and climatological measurements. The network will provide the basis for assessing the effect of climate change in other watersheds where long term hydrometric and climate data are not both available.

Workshop on Atmospheric Issues in Atlantic Canada

Preliminary observations are, for example, that due to colder winter temperatures, there has been a greater retention of the snowpack resulting in increased spring runoff. The colder winter temperatures have also increased the number of days of ice cover in the rivers and could have affected aquatic biota.

With respect to chemical changes, Clair described in his verbal presentation the effect of climatic change upon the export of dissolved organic carbon (DOC) and nitrogen (DON). (See also the poster presentation by Clair and Ehrman, p.122). The authors used a neural network approach to examine relationships between climate and geography upon discharge, DOC and DON from 15 river basins in the Atlantic Region between 1983 and 1992. The export of DOC is important because it is associated with the transport of heavy metals, plays a major role in REDOX reactions and acid-base relationships. Therefore, DOC provides a linkage between climatic change and regional acidification. Clair pointed out that acidified lakes are not recovering to the degree one would expect from the recent reductions in atmospheric sulphur deposition because a dry year will release into freshwaters sulphur that has been stored in the basins (including wetlands) - if Canada becomes dryer, it could take several decades to clean excess sulphur out of freshwater systems.

With respect to the possible effects of climatic change upon freshwater biota, Clair suggested that if lakes become warmer with a longer growing seasons, coldwater species may disappear due to the loss of their habitat including a reduction of oxygen in deep water. Alternatively, a shorter duration of the ice cover may reduce winter kill, unless this effect is overcome by reductions in lake depth. Lowering of the water table and reduction of wetlands may increase the water clarity, lower the thermocline, and increase algae and benthic life.

Wetlands, as emitters of CO₂ and CH₄ (both greenhouse gases) could also play a feedback role in climatic change, as described in the poster by Dalva *et al* (p.123). As part of an ongoing study on the carbon cycle of wetlands in Kejimikujik National Park in south-central Nova Scotia, the aim of their study was to quantify CH₄ and CO₂ emissions from soils in two wetlands in the Pine Marten watershed and relate the emissions to variations in plant cover, water table position and thermal regime. Seasonal fluxes of CH₄ were positively correlated with water table position (this means that lowering the water table in a dryer climate would decrease CH₄ emissions and, therefore, greenhouse gas forcing).

Emissions of CH₄ were also related to the microtopology of the catchment. Hummocks with average water table depth > 20 cm showed the smallest emissions while wetter depression areas near stream banks with water table depth < 15 cm showed the largest. Conversely, fluxes of CO₂ were negatively correlated with water table position (this means that lowering the water table in a dryer climate could increase greenhouse gas forcing).

Another poster presented in the session on Regional Acidification by Watt (p.99) postulated a possible link between climatic change and regional acidification. A decrease in water temperature in Nova Scotia rivers due to the eruption of Mount Pinatubo in 1992 may have lead to a temporary reversal in the recovery of salmon from acidification.

iv) Effects upon terrestrial ecosystems

D. Price (p.140) gave a verbal presentation on the terrestrial implications of climatic change. He stated that our circumpolar boreal forest and tundra ecosystems, which characterise much of Canada, are particularly sensitive to such changes, not only because of environmental effects on vegetation growth, but also because of expected increases in the frequency of natural disturbances (particularly wildfires and insect infestations), and because of the effects of warming on decomposition rates in organic soils and wetlands. The latter processes may contribute to run-away feedbacks (i.e., accelerated releases of greenhouse gases from natural ecosystems), while the former may lead to major changes in the vegetation's capacity to sequester atmospheric carbon.

Price pointed out that terrestrial ecosystems may be the "missing" carbon sink. However, he was quick to add that terrestrial ecosystems may not continue to be a carbon sink under a future warmer and dryer climate. Drying of wetlands and melting of the permafrost could result in an increase of releases of carbon dioxide and methane. More frequent and intense forest fires in a warmer and dryer climate could release large quantities of carbon dioxide.

Although the changes in growing conditions for forests that result from an increase in greenhouse gases may be less pronounced in the Atlantic region than they might be in the Prairie Provinces, they might still have significant ecological effects in term of forest composition, and its spatial and age-class structure. These effects could be quite pronounced near the present boundaries of vegetation regions. Price showed some of the results from running the FORSKA 2 ecosystem process model in the Atlantic region. For example, at Frobisher Bay spruce could invade a treeless terrain. At Gander NF the model indicates that there would be a major shift to Eastern hemlock and a slight reduction in biomass. However, the question remains: will terrestrial species including trees be able to "follow" quickly enough the geographical shifts in favourable growing regions?

The poster of Yanni *et al* (p.143) showed how forest hydrology simulations could predict future hyrological conditions in forests such as soil moisture, evapotranspiration, snowpack accumulation, stream discharge, soil and stream temperature, and depth and duration of frost in the ground. The methodology was tested in two watersheds: the Turkey Lakes north of Lake Superior, and Kejimikujik National Park in Nova Scotia.

v) Effects upon marine ecosystems

A changing climate could affect both the physical aspects of the ocean and its marine life. Kertland in her verbal presentation stated that models indicate that sea level could rise from 3 to 6 cm per decade, with obvious effects upon coastal infrastructures. The poster of Thomas (p.141) summarized the results of four studies presented at the Fourth International Workshop on Wave Hindcasting and Forecasting, Oct. 16-20/95, Banff, AB. Several recent extreme storm and wave events in the northwest Atlantic have exceeded published estimates of extreme wave climatology. The most notable events were the Hallowe'en Storm of October 1991 and the Storm of the Century, March 1993, where 16 to 17 m significant wave heights were measured by moored buoys off the edge of the Scotian shelf. It is not clear if these events are an indication of a changing wave climate, or how they relate to natural climate variability. No increase in wave climate was found off the east coast of the US over the last 15 years, however over the northeast Atlantic wave analyses do show an increase in significant wave height over the last 30

years. This increase was linked to corresponding changes in the sea level pressure patterns and the North Atlantic Oscillation (NAO), which is associated with changes in the surface westerlies across the North Atlantic. High NAO indices indicate stronger westerlies and a deeper Icelandic low pressure centre. There has been an increasing trend in the NAO since the late 1970s, with unprecedented strongly positive NAO indices since 1980.

K. Mann in his verbal presentation (p.127) presented evidence for a strong influence of atmospheric factors on fluctuations in Northern Cod stocks. The Icelandic low pressure area has been relatively intense during the past few years, causing cold and windy winters over the Labrador Sea. This has had the effect of pushing the cold water to greater depths and increasing the winter ice cover, conditions that are both adverse for cod larvae as the bloom of the plankton on which the larvae feed is delayed, thereby slowing down metabolism and growth. In the absence of overfishing, the cod stocks may be somewhat resilient to such adverse environmental changes; overfishing may have rendered the stocks sensitive to these changes and led to the recent decline in the Northern Cod stocks.

b) The present situation with respect to policy

R. Findley gave a verbal presentation on the evolution of policy measures with respect to climatic change. He began by saying that, to date, the issue has been driven from the top down by scientists; the general public has not been as concerned with it as they have been with other issues such as acid rain and hazardous pollutants. Efforts thus far have been led by international coordinating bodies, bureaucratic and semi-political. The Intergovernmental Panel on Climate Change (IPCC), under the joint aegis of the World Meteorological Organization and the UN Environment Programme, began work in 1988 to carry out a scientific assessment of climatic change as a foundation for international agreements on reducing emissions of greenhouse gases. The first assessment was issued in 1991 and there is a second assessment due very soon.

The Berlin Mandate resulting from a meeting in that city elaborated on the policies and measures that would be needed; the various countries have agreed to develop a protocol for quantitative emission reductions and have agreed to develop by 1997 a long-term post-2000 negotiating strategy.

Internationally, Canada is beginning negotiations to seek key alliances. Nationally, the goal at the moment is to reduce emissions for greenhouse gases to 1990 values. In November 1995, a meeting was held among Canadian ministers. For the moment, a voluntary advocacy approach will continue - provinces will produce status reports on emissions of greenhouse gases. The National Air Issues Coordinating Committee (NAICC) will continue to lead the development of the national plan.

c) Workshop deliberations

Question 1: What aspects of climatic change are of greatest importance in the Atlantic Region?

1. Despite the uncertainty in the projections of climatic change in the Atlantic Region, it is important to have an estimate of the sensitivity of Atlantic Canada resources to climatic changes in either direction. *Such resources include agriculture, forests, wildlife, the fishery, coastal infrastructure, transportation, tourism and the human population.*

2. It is important to continue the database of climatic variables to enable us to distinguish natural climatic variability from changes caused by human activities.

Question 2: What results, in terms of a) improvements of our understanding of the environment, and b) changes in the environment, would we like to see from our efforts in the next five to ten years?

1. A list of components of the Atlantic Canada environment (both natural and human) that are sensitive to changes to climatic variables (in either direction), and those that are not. *Indicators would include biodiversity, health, productivity, availability for human use, and susceptibility to changes in sea level and storm surges.*

2. Based upon Item 1 above, protective and adaptive measures including lifestyle changes that will be robust with respect to uncertainties in climatic change projections. *Because of the uncertainty in predictions by Global Circulation Models of changes in regional climate, it would be prudent to take measures that would make us less susceptible to climatic change in either direction.*

3. A continuous database of climatic variables with sufficient temporal and spatial resolution to detect any anthropogenic changes and allow one to estimate the risk to the sensitive components of the environment. *Because of natural fluctuations, both short- and long-term, in climatic variables, a commitment to long-term monitoring is needed.*

Question 3: What activities are needed to achieve these results?

1. Formation of an interdisciplinary and multisectoral (public, private, academia) group to develop a matrix of sensitivity of various components of the environment of the Atlantic Region to climatic change. *One dimension of the matrix would be the aspect of the resource (using indicators such as freshwater availability or forest biodiversity); the other would be climatic variables such as temperature, precipitation, frequency of sea level rise or storm surges. This activity would make use of existing information, ecosystem studies and modelling results.*

2. Given the results from the sensitivity matrix above, the group in Item 1 will suggest protective and adaptive measures for the sensitive components of our ecosystem.

3. The multisectoral group in Item 1 will oversee the monitoring of climatic changes in the region. *An attempt will be made to link regional climatic changes with those occurring on a continental and global scale.*

4. Climate prediction models should be improved so that there is more confidence in their predictions of possible changes in regional climate.

9. Overall Conclusions and Recommendations of the Workshop

In his remarks at the closing session, G. Bangay, Atlantic Regional Director-General for Environment Canada, observed that all of the issues covered at the workshop were initially only of scientific interest but, because of public concern about health and the environment, had come into the venue of policymakers. He stressed that linkages between scientists and policymakers must continue to strengthen and was pleased to see that the workshop had contributed to these linkages. He noted that the findings of the workshop would be reported the very next day at a meeting between Environment Canada officials and senior managers from provincial governments in the Atlantic Region.

Bangay stated that it was gratifying to see that, in the workshop, global issues were interpreted on the regional scale. He also stressed the need for cross-fertilization of knowledge among the various atmospheric issues and for research and policy efforts to, as much as possible, meet the needs of more than one issue. Not only were there good scientific reasons for doing so, but shrinking budgets in both the public and private sectors would make it more and more necessary in the foreseeable future. He encouraged the use of the ecosystem approach and stated that Environment Canada would be willing to play the part of facilitator among scientific disciplines and various sectors, both public and private.

Although some of the findings of the workshop were relevant to only one or two issues, there were several strong common threads running through all of the issues, and which merit being highlighted as overall conclusions of the workshop. These overall conclusions, which are listed below, will hopefully serve as guidance for the future planning of atmospheric research and policy in the Region.

The overall conclusions and recommendations of the workshop are as follows:

1. The ecosystem approach should be followed as much as possible in the planning of research. This has been done for the past 20 or more years in, for example, Kejimikujik National Park and should be continued. Because ecosystems are usually subject to more than one atmospheric stress, it makes sense to focus efforts in one geographical area to better determine the linkages and synergisms among the various stresses. Monitoring of atmospheric qualities (see Item 2 below) and ecosystem responses in the Region could yield dose-response relationships for combinations of stresses that will be useful in establishing environmental targets that are relevant to the Region. For example, the workshop brought out the need for better information on critical loads for acidic deposition on the brown freshwaters that are common in the Region. In addition, more information is needed on the effect of increased UV-B radiation on forest species. It was also suggested that an ecosystem study on mercury be initiated as a test case. Ecosystem studies are the way to bring scientists from various sectors together to study more than one problem.

2. Throughout the workshop, it was stressed that it is essential that a commitment be made for continuous, long term monitoring of atmospheric qualities that are relevant to all of the atmospheric issues: acidic deposition, tropospheric oxidants, UV-B radiation, total column ozone, hazardous air pollutants and climatic variables, as well as the anticipated ecosystem responses. All too often in the past, badly needed long-term data simply do not exist. Some of these long-term measurements could be made as part of the ecosystem studies and be incorporated in the Environmental Monitoring and Assessment Network (EMAN). Not only are such measurements needed to better define a problem, such as in the case of hazardous air pollutants, but they are needed to assess the effects of policy measures with respect to, for example, regional acidification, low-level oxidants and stratospheric ozone depletion.

3. The development of Integrated Assessment Models (IAMs) that are relevant to the Region should be encouraged. These models should address more than one atmospheric issue, such as regional acidification and low-level oxidants, and should include ecosystem effects. The development of these models should make use of information gained from ecosystem studies, long-term monitoring and Canadian participation in projects such as the North American Regional Study on Tropospheric Oxidants (NARSTO). These models could be used to assess the possible effects of proposed emission control policies and, when combined with economic data, to develop cost-effective strategies. This could be especially useful for regional acidification, since deposition is presently above critical loads in the Atlantic Region.

4. With respect to climatic change, it was apparent that the projections by General Circulation Models (GCMs) of changes in regional climate due to increasing greenhouse gas concentrations are very uncertain, even to the direction of the changes. Therefore, it was concluded that the most prudent step to take would be to form a multidisciplinary and multisectoral group to develop a matrix of sensitivity of various regional resources, for example freshwater availability or forest diversity, to climatic changes *in either direction*. This activity would make use of existing monitoring and modelling results, and ecosystem studies. This group could then suggest protective and adaptive regional measures against climatic change.

5. Finally, in developing regional research and policy, it would be prudent to form as many partnerships as possible among various elements of the public and private sectors, including academia and industry. Not only would pooling intellectual and financial resources be beneficial in these days of restraint, but it could foster an atmosphere of mutual rather than adversarial interest in addressing atmospheric issues.

APPENDIX A

WORKSHOP AGENDA

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Day 1: Regional Acidification and Low-level Oxidants

(Tuesday, 28 November 1995)

Session chair: Steve Beauchamp (Atmospheric Environment Branch, EC-AR, Bedford, Nova Scotia)

0800: Set up posters for acidification and oxidants

0830: Welcome (Tom Clair, Environmental Conservation Branch, EC-AR, Sackville, New Brunswick)

0835: **International Agreements and National Policy Initiatives for Acidifying and Oxidizing Substances** (Kathleen Hedley, EPS, Ottawa, Ontario)

0900: **National and International Science Updates for Acidification and Oxidants** (Guy Fenech, AES, Downsview, Ontario)

0925: **Regional Control Programs for Acidifying and Oxidizing Substances** (Denis Marquis, New Brunswick Department of Environment, Fredericton, New Brunswick)

0950: **Trends and Predictions of Acidifying Substances in Eastern North America** (Don McKay, AES, Downsview, Ontario)

1015: Break

1035: **Aquatic Acidification: New Observations, Concerns and Activities** (Dean Jeffries, ECS, Burlington, Ontario)

1100: **Ozone Patterns and trends in Eastern Canada** (Tom Dann, EPS, Ottawa, Ontario)

1125: **The Eastern Canadian 1996 Oxidants Field Study** (Maris Lusi, AES, Downsview, Ontario)

1135: **Ecological Effects of Oxidants** (Ron Pearson, OMEE, Toronto, Ontario)

1200: **Health Effects of Oxidants** (Dave Stieb, Health Canada, Ottawa, Ontario)

1225: Lunch and poster session

1400: Charge to workshop groups (2 concurrent sessions, regional acidification & low-level oxidants)

1415: Workshop deliberations (Refreshments available 1500-1530)

1545: Workshop summaries and discussions

1645: Conclude and take down posters

APPENDIX A: WORKSHOP AGENDA

Day 2: Stratospheric Ozone Depletion and Hazardous Air Pollutants (Wednesday, 29 November 1995)

Session chair: Kevin Percy (CFS, Fredericton, New Brunswick)

0800: Set up posters for ozone depletion and hazardous air pollutants

0830: Welcome (Tom Clair, Environmental Conservation Branch, EC-AR, Sackville, New Brunswick)

0835: **National/Regional Policy Initiatives and Control Strategies for Ozone Depleting Substances and Hazardous Air Pollutants** (Joe Kozak, Environmental Protection Branch, EC-AR, Dartmouth, Nova Scotia)

0900: **Ozone Depletion and Atmospheric Ultraviolet (UV) Radiation Research** (David Wardle, AES, Downsview, Ontario)

0925: **Quantifying the Potential Effects of Ozone Depletion on Aquatic Systems** (John Cullen, Dalhousie University, Halifax, Nova Scotia)

0950: **Effects of Increased Ultraviolet Radiation on Terrestrial Plants** (Yousef Papadopoulos, Agriculture Canada, Nappan, Nova Scotia)

1015: Break

1035: **Human Health Effects of UV Exposure** (Yvon Deslauriers, Health Canada, Ottawa, Ontario)

1100: **Toxic Substances Assessment and Management Processes Used by Environment Canada** (Bill Ernst, Environmental Protection Branch, EC-AR, Dartmouth, Nova Scotia)

1125: **Deposition Patterns of Air-borne Toxic Chemicals in Eastern Canada** (Bill Strachan, ECS, Burlington, Ontario)

1150: **Marine Ecological Effects of Air-borne Toxic Chemicals** (Gareth Harding, DFO, Bedford Institute of Oceanography, Dartmouth, Nova Scotia)

1215: Lunch and poster session

1400: Charge to workshop groups (2 concurrent sessions, stratospheric ozone depletion and hazardous air pollutants)

1415: Workshop deliberations (refreshments available 1500-1530)

1545: Workshop summaries and discussions

1645: Conclude and take down posters

APPENDIX A: WORKSHOP AGENDA

Day 3: Climatic Change (Thursday, 30 November 1995)

Session chair: Joe Kozak (Environmental Protection Branch, EC-AR, Dartmouth, Nova Scotia)

0800: Set up posters for climatic change

0830: Welcome (Tom Clair, Environmental Conservation Branch, EC-AR, Sackville, New Brunswick)

0835: **Policy and Politics of Climate Change** (Rick Findlay, EPS, Ottawa, Ontario)

0900: **National and International Science Update for Climate Change**
(Pam Kertland, AES, Downsview, Ontario)

0930: **Climate Change Scenarios for Eastern Canada** (Grace Koshida, AES, Burlington, Ontario)

1000: Break

1030: **Aquatic Implications of Climate Change** (Peter Dillon, OMEE, Dorset, Ontario, presented by T. Clair)

1100: **Terrestrial Implications of Climate Change** (David Price, CFS, Edmonton, Alberta)

1130: **Atmospheric Factors in Fluctuations in Northern Cod Stocks** (Ken Mann, DFO, Bedford Institute of Oceanography, Dartmouth, Nova Scotia)

1200: Lunch and poster session

1330: Charge to workshop groups (two groups for climatic change)

1345: Workshop deliberations (refreshments available 1500-1530)

1530: Workshop summaries and discussions

1600: Final wrap-up (Garth Bangay, Regional Director General, EC-AR)

1630: Conclude and take down posters

APPENDIX A: WORKSHOP AGENDA

ACRONYMS:

AES	Atmospheric Environment Service of Environment Canada
CFS	Canadian Forest Service of Natural Resources Canada
DFO	Canadian Department of Fisheries and Oceans
EC-AR	Environment Canada - Atlantic Region
ECS	Environmental Conservation Service of Environment Canada
EPS	Environmental Protection Service of Environment Canada
OMEE	Ontario Ministry of Environment and Energy

APPENDIX A: WORKSHOP AGENDA

APPENDIX B

WORKSHOP REGISTRANTS

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APPENDIX B: WORKSHOP REGISTRANTS

APPENDIX C

ABSTRACTS AND SUMMARIES

(IN ALPHABETICAL ORDER BY AUTHOR)

VERBAL AND POSTER PRESENTATIONS FOR DAY ONE:

TUESDAY 28 NOVEMBER 1995

ACIDIFICATION AND LOW-LEVEL OXIDANTS

APPENDIX C: REGIONAL ACIDIFICATION AND LOW-LEVEL OXIDANTS

Calculating critical S and N loads and current exceedances for upland forests in Eastern Canada.

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ABSTRACT (POSTER PRESENTATION)

A steady-state mass-balance model is proposed to calculate critical loads of S and N deposition for maintaining acceptable long-term acidity levels for upland forests in Eastern Canada. Preliminary estimates about critical S and N loads were obtained using existing information about soils, vegetation and atmospheric ion deposition for 2 case studies: Southern Ontario and New Brunswick. Considered are: wet + dry atmospheric deposition of all major cations (H^+ , Ca^{2+} , Mg^{2+} , K^+ , Na^+ , NH_4^+ and anions (SO_4^{2-} , NO_3^- , Cl^- , HCO_3^-); availability for plant uptake of N, Ca, Mg and K nutrients in the rooting space of each soil; nutrient uptake and storage in the growing woody biomass of the forest stands; estimates of soil weathering based on bedrock type, soil parent material origin and texture class; and mean annual air temperature, precipitation and evapotranspiration. From this, regional isopleth maps are generated to depict:

1. current deposition patterns;
2. critical acidification loads and their current exceedances (or non-exceedances) for two acidification effects criteria for soil solutions, namely
 - (a) acceptable Al concentrations ($[Al]_{leach,crit}$), and
 - (b) acceptable Al to base cation concentration ratios ($[Al]/[BC]_{leach,crit}$);
3. critical N-eutrophication loads and their current exceedances for acceptable levels of NO_3-N concentrations in soil solutions ($[NO_3-N]_{leach,crit}$).

For Southern Ontario, it was found that its northern part of the study area (part of the Canadian Shield) is currently subjected to atmospheric S and N deposition in excess of critical loads, with $[Al]_{leach,crit}$ set at 0.02 meq/l, or $[Al]/[BC]_{leach,crit}$ set at 0.15 eq/eq. This sensitivity to acid precipitation is, as calculated, primarily due to shallow and weathering-resistant soils and soil parent materials (mostly granitic). The middle portion of Southern Ontario is calculated to receive N slightly in excess of the N eutrophication limit, when $[NO_3-N]_{leach,crit}$ is set at 0.1 meq/l. Considerable co-deposition of base cations (Ca, Mg, K) in the middle and southern part of the study area alleviates some of the atmospheric acidification stress. This stress is further neutralized by the soils and bedrock of this region (predominantly calcareous).

APPENDIX C: REGIONAL ACIDIFICATION AND LOW-LEVEL OXIDANTS

For New Brunswick, S and N exceedances were mainly calculated for the southern and eastern coast regions (Fundy coast, and Bay of Northumberland coast, respectively). It was further calculated that harvesting of upland forests increases current exceedances: somewhat for conventional harvest operations, and more extreme for whole-tree harvesting.

The Northeast Regional Air Quality Committee (NERAQC) - a First Adventure into Cross-border Cooperative Action on Air Issues and Protected Areas

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ABSTRACT (POSTER PRESENTATION)

This paper describes a new organization - THE NORTHEAST REGIONAL AIR QUALITY COMMITTEE (NERAQC) operating in Eastern North America that is attempting to work across jurisdictional boundaries for the protection and improvement of air quality in protected areas in the Northern New England in the U.S. and the Atlantic region of Canada. NERAQC will have membership from federal, state and provincial land management and regulatory agencies from both Canada and the United States. The paper details the mission, objectives and activities of the committee and considers the future the organization.

Trends in Acid Deposition in the Atlantic Provinces (1980-1994)

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ABSTRACT (POSTER PRESENTATION)

Environment Canada monitors the chemical constituents of precipitation at five sites in the Atlantic provinces as part of the nation-wide Canadian Air and Precipitation Monitoring Network (CAPMoN). These sites are situated downwind of the major sources of acidifying pollutants in North America and have been monitoring daily precipitation chemistry and amount since the early 1980's. Total U.S. and Canadian sulphur dioxide emissions (the main contributor to "acid rain") have declined by 16.5%

APPENDIX C: REGIONAL ACIDIFICATION AND LOW-LEVEL OXIDANTS

from 1980 to 1992. Because of the "noise" in the data caused by a large meteorologically-induced natural variability, many years of careful data collection at the CAPMoN sites have been necessary to definitively detect the effect on precipitation chemistry of this decline in upwind emissions. Statistically significant linear decreases of 28 to 40% in precipitation sulphate concentration (corrected for sea salt) are now detectable at the four CAPMoN sites located in Nova Scotia (Kejimikujik, 1980-1994; Jackson, 1984-1994), New Brunswick (Harcourt, 1984-1994) and on the Island of Newfoundland (Bay d'Espoir, 1982-1994). A decrease of 25% has occurred at the site in Labrador (Goose Bay, 1984-1994), but this is not statistically significant. It should be noted that no significant trends in hydrogen ion concentration were detected at any of these sites.

In addition to temporal trends at the CAPMoN sites, changes in the spatial distribution of sulphate deposition throughout the Atlantic region were also examined. The much larger data set of the National Atmospheric Chemistry (NAtChem) data base, which is maintained by Environment Canada and contains most of the federal and provincial acid rain data collected in Canada, was used to produce annual maps of the precipitation-weighted average sulphate deposition (corrected for sea salt) in the Atlantic provinces from 1980 to 1993, using only those sites and data meeting the quality criteria of the Unified Deposition Data Base Committee. Tracking the movement of specific deposition isopleths across the region during the period 1980 to 1993 showed that they have shifted to lower values over the 14 years covered by the maps. Therefore, a general decrease in sulphate deposition has occurred in the Atlantic provinces since 1980, when most of the region received sulphate deposition greater than 12 kg/ha/yr. In recent years, most of the region has received less than 12 kg/ha/yr.

The majority of the aquatic ecosystems of the Atlantic provinces are very sensitive to acid deposition. The critical load for much of the Atlantic provinces is less than 8 kg/ha/yr, which is surpassed in most of the region, with the exception of Labrador. Based on preliminary projected deposition fields for future years produced by an atmospheric model (Atmospheric Environment Service Lagrangian Model) using estimated future emissions, much of the Atlantic provinces will likely continue to receive deposition greater than the critical load even after the sulphur dioxide emission reductions legislated by the U.S. Clean Air Act have been fully implemented by the year 2010. Therefore, the environment of the Atlantic provinces is expected to continue to be under attack from acid rain for the foreseeable future, and will require: continued monitoring of precipitation chemistry and impacted ecosystems to determine the progress of control measures; research into the effect of other pollutants on acidification (e.g. nitrogen, base cations); and further modelling studies to refine the projected impacts and to estimate the emission reductions that would be required to meet a specific deposition target for the region.

APPENDIX C: REGIONAL ACIDIFICATION AND LOW-LEVEL OXIDANTS

Ozone, CO and VOC Measurements at Kejimikujik National Park, Nova Scotia, During NARE 1993.

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ABSTRACT (POSTER PRESENTATION)

Ground-level ozone (O₃), carbon monoxide (CO) and selected (C2-C5) volatile organic compounds (VOCs) were measured during the NARE study period (mid-July to mid-September, 1993) at Kejimikujik, an inland site located in central Nova Scotia. Both ozone and carbon monoxide were variable over time with periodic peaks in concentrations. Details of a pollution episode on August 28 are presented. Ozone and CO concentrations at Kejimikujik were high when a weak pressure gradient with modest southwesterly flow, warm temperatures and clear skies occurred in the warm sector in advance of an approaching cold front. On this date, surface (1000 mb) back-trajectories indicated transport from the Boston-New York corridor while higher level back-trajectories (925 mb and 850 mb) were more continental in nature. Ozone and CO for the month of August were significantly correlated and, based on air parcel trajectory analysis, CO was indicative of anthropogenic pollutant transport from emission source regions during the study period.

Short-term Chemistry Variations in Acidified Nova Scotian Rivers and Streams

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ABSTRACT (POSTER PRESENTATION)

Sudden large changes in the chemical conditions of streams and rivers are most likely to adversely disrupt the living conditions of fish and aquatic invertebrates. In order to determine the frequency of these potentially harmful events, I studied water chemistry data collected weekly over a three year period at three basins of different sizes, located in south-central Nova Scotia and hourly at the smallest of these basins. There were clear differences in the seasonality of these low frequency events, as winter and spring had the greatest number of short events, while during summer and fall, events few less frequent but were longer lasting. These results showed that weekly sampling did not allow a reasonable evaluation of winter and spring events, but seemed to capture the summer and fall one.

APPENDIX C: REGIONAL ACIDIFICATION AND LOW-LEVEL OXIDANTS

Regional precipitation and surface water chemistry trends in southeastern Canada (1983-1991)

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ABSTRACT (POSTER PRESENTATION)

We analyzed for trends of acidification related variables from 1983 to 1992 in precipitation concentrations and deposition at six sites and surface water concentrations at 111 sites located from central Ontario to eastern Newfoundland. Precipitation showed significantly decreasing H^+ and SO_4^{-2} concentrations and deposition in central and eastern Ontario and at one of two sites in Québec (deposition only). For Ontario surface water sites, only increasing or stable SO_4^{-2} trends were observed, and these had concomitant increasing and decreasing trends for pH and (or) acid-neutralization capacity (ANC). Despite a considerable number of lakes showing decreasing SO_4^{-2} trends in Québec, pH and ANC also decreased. Québec was also the only region showing evidence of increasing NO_3^- . The opposite situation was observed in Atlantic Canada lakes where despite increasing SO_4^{-2} , the dominant trend observed for pH and ANC was increasing. Trends observed for pH and ANC were used to classify the acidification status of our surface water sites: 60 of the 111 sites were found to be stable (i.e. showing no trends), 17 were continuing to acidify, and 34 were improving.

Spatial Distribution of Ozone on the Lepreau Peninsula using Passive Ozone Monitoring.

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ABSTRACT (POSTER PRESENTATION)

Ozone distribution across a forested peninsula receiving long range transported air pollution was examined using passive ozone monitors (CanOxy Plate) at nine open sites over a six week period. Weekly ozone isopleths (ppmh) were generated and overlain and registered to the same map base showing Normalized Vegetation Index (NDVI) and elevation using a GIS. Mean wind vectors and average wind speeds were also

APPENDIX C: REGIONAL ACIDIFICATION AND LOW-LEVEL OXIDANTS

determined for each sample period. The maps produced for periods when the mean wind vector was from the south east (associated with the highest ozone concentrations) indicated that the ozone was depleted inland. This apparent rate of depletion seems to increase as air passes over areas of higher vegetation index. The results indicate that the use of passive ozone monitors has some potential for the determination of ozone depletion rates or deposition over the landscape with different vegetation index categories.

Ozone Patterns and Trends in Eastern Canada

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ABSTRACT (VERBAL PRESENTATION)

This presentation will provide a summary of ground level ozone measurements for eastern Canada and the eastern United States. Seasonal and diurnal patterns in ozone at Atlantic Canada sites will be compared to those for sites in neighbouring regions. Features of ozone episodes (concentrations of ozone greater than the Canadian maximum acceptable air quality objective value of 82 ppb) will be discussed in detail. Available measurement data for nitrogen oxides (NOX) and volatile organic compounds (VOC) at Atlantic sites will also be provided and compared to other Canadian sites. Results of recent trend analysis of daily maximum ozone concentrations for eastern sites will be presented and discussed.

National and International Science Updates for Acidification and Oxidants

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ABSTRACT (VERBAL PRESENTATION)

Canada has waged battle against acid rain for more than 2 decades. In 1985, we signed the Helsinki Protocol (the 30% Club). Almost 10 years later, we signed the Oslo Protocol. The most significant difference between the 2 protocols has been the "operationalization" of the concept of "working toward critical loads". This approach is a scientific method of linking air pollutant emission reductions on national and international scales to environmental benefits. It requires quantitative estimates of the

APPENDIX C: REGIONAL ACIDIFICATION AND LOW-LEVEL OXIDANTS

effects of acidification on receptors such as aquatic or terrestrial ecosystems. Thus, it requires good integration of a number of scientific activities such as predicting changes in deposition given changes in emissions, determining the maximum load of a given pollutant that will not produce significant changes in the structure or the function of the ecosystem, documenting, validating and mapping the information. This approach is being used to develop the Canadian Strategy for Acidifying Emissions post-2000. A similar, but expanded approach, is being used in preparing for negotiations for a second NO_x protocol under the aegis of the UN-ECE Convention Long-Range Transboundary Air Pollution. A summary of the scientific activities that support these policy initiatives will be presented.

A Database for Taxonomy Records for the LRTAP (Long Range Transport of Air Pollutants) Program, BEM (Biological Effects Monitoring) Project

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ABSTRACT (POSTER PRESENTATION)

A database was designed to record faunal collections for the Biological Effects Monitoring project of the Long Range Transport of Air Pollutants program. Taxa collected from all regions associated with the project were listed within their respective taxonomic hierarchies. A relational database (dBase IV) was used to develop a taxonomic list which could be sorted and/or queried at any level of taxonomic complexity.

International Agreements and National Policy Initiatives for Acidifying and Oxidizing Air Pollutants

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ABSTRACT (VERBAL PRESENTATION)

Canada is a signatory to a number of international agreements related to controlling, or reducing emissions of acidifying and oxidizing air pollutants. The main fora for these international agreements is the 1979 Convention on Long Range Transport of Air Pollution (LRTAP) under the United Nations Economic Commissions for Europe. Under this umbrella Canada has signed four protocols related to emission reductions acidifying

APPENDIX C: REGIONAL ACIDIFICATION AND LOW-LEVEL OXIDANTS

or oxidizing pollutants: two protocols reducing emissions of sulphur dioxide (SO₂) (Helsinki, 1985 and Oslo, 1994), one protocol stabilizing emissions of nitrogen oxides (NO_x) (Sophia, 1988), and one protocol committed to reducing emissions of volatile organic compounds (VOCs) (Geneva, 1991). To date Canada has ratified two of these; the first sulphur protocol and the NO_x protocol.

In addition to our commitments under the LRTAP Convention, Canada and the United States signed the Air Quality Agreement in 1991, which contains further obligations regarding emissions of acidifying and oxidizing pollutants. While the main objective of the Air Quality Agreement is to control transboundary air pollution between the two countries, the existing commitments target acidifying pollutants (SO₂ and NO_x).

Canada has domestic programs that enable the delivery of our international commitments. The Canadian Acid Rain Program was initiated in 1985 when the seven most eastern provinces agreed to reduce emissions of sulphur dioxide by 40% by 1994. SO₂ emissions for these seven eastern provinces in 1994 were 1.7 million tonnes, significantly below the cap of 2.3 million tonnes. In November 1994, Canadian Ministers of Environment and Energy agreed to work together and develop a National Strategy on Acid Rain which will ensure our international commitments are met past the year 2000. The National Strategy is being developed through a multistakeholder task group, and will address the need for further emissions reductions in the U.S. and Canada required to mitigate the negative impacts on human health, aquatic and terrestrial ecosystems and visibility.

Phase I of the NO_x/VOC Management Plan, which was accepted by Ministers in 1990, outlines both prevention and remedial emissions reduction measures aimed at resolving Canada's ground level ozone problem by 2005. Phase II of the program is currently being developed by federal and provincial governments, and will likely target the two areas in Canada with the most severe ground level ozone problems: the Windsor-Quebec Corridor and the Lower Fraser Valley.

Aquatic Acidification: New Observations, Concerns and Activities

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ABSTRACT (VERBAL PRESENTATION)

The Canada/US Air Quality Agreement specifies SO₂ emission controls to reduce acidification effects in North American ecosystems. Emission targets for Canada were met in 1994 while US targets will be met by 2010. The magnitude of the controls was established in large part by the information presented in the Canadian "1990 Assessment" and the US NAPAP reports. Several observations made since then however, support the contention that these emission controls are a good and necessary first step, but they are unlikely to fully reverse aquatic acidification. The ambiguous

APPENDIX C: REGIONAL ACIDIFICATION AND LOW-LEVEL OXIDANTS

results of acidification trend analyses show that several factors beyond the existing reductions in sulphate deposition (e.g. continuing deposition of NO_x pollutants, climatic interactions, natural organic acids) influence changes in water acidity. A new "Assessment" is being prepared to support development of a post-2000 strategy for further emission controls in Canada (and the US). It will make extensive use of an Integrated Assessment Model (IAM) to design the strategy. As shown by the remarkable size and quality of the most recent conference on acid rain (Göteborg, Sweden, June 1995), international attention on the acid rain issue is still increasing.

Trends in Surface Water Acidification at Ecological Monitoring Sites in Southeastern Canada (1981-1993)*

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ABSTRACT (POSTER PRESENTATION)

Atmospheric deposition and surface water chemistry have been monitored intensively at 5 geologically "sensitive" sites in southeastern Canada. The sites receive differing acid inputs that span the entire range found in Canada. Surface water data collected at 9 stations from 1981 to 1993 for SO_4^{2-} , NO_3^- , Alkalinity, DOC, pH, Ca^{2+} and Mg^{2+} have been analyzed to detect monotonic trends. Similarities between the temporal patterns and trends for SO_4^{2-} in deposition and surface water suggest that they are strongly linked at our sites. Our 13-year datasets showed significant negative SO_4^{2-} trends at the 3 Ontario sites and a positive trend in Nova Scotia. A climatically-induced SO_4^{2-} increase in northwestern Ontario has been reversed. Mobilization and export of adsorbed SO_4^{2-} and/or reoxidized S from the basins of central Ontario sites is delaying their recovery. Two of our 9 stations (in Quebec and central Ontario) are continuing to acidify. The 2 Nova Scotia stations have the highest DOC levels and both exhibit a decreasing trend. Ionic compensation for declining SO_4^{2-} varies from station to station, sometimes involving an Alk increase, sometimes a base cation decrease, and sometimes more complex combinations. Additional factors (e.g. climatic variation) also influence variable trends, and data records longer than those presently available will be needed to unequivocally verify acidification recovery.

* Poster originally presented in June, 1995 at the international conference "Acid Reign '95?", Göteborg, Sweden. The paper now in press (Wat. Air Soil Pollut.).

APPENDIX C: REGIONAL ACIDIFICATION AND LOW-LEVEL OXIDANTS

Abundance and distribution of fish-eating birds in Kejimikujik National Park, Nova Scotia (1988 - 1995)

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ABSTRACT (POSTER PRESENTATION)

The breeding population of piscivorous birds was studied for seven years in 40 lakes in Kejimikujik National Park (385 km²) as part of Environment Canada's program to determine the effects of acid precipitation on the aquatic environment. The data obtained confirmed that the successful breeding of fish-eating birds such as Common Loon and Common Merganser is controlled by the amount of fish available in a lake which is in turn controlled by the nutrient supply (phosphorus) in the lake. The number of residential loon pairs remains stable (~39 pairs) while the number of chicks fledged may vary annually (mean 11.0, range 5 to 18). A large number of the non-breeding loon population spend their summer in the ocean. The relative closeness to the sea coast (~40 to 60 km in two directions) ensures that all the suitable loon territory in these lakes is soon filled when they become vacant. This may give a partial explanation of the low ratio (0.29) of loon chick/ residential pair in Kejimikujik compared to other continental populations distant from the sea. Some of the annual fluctuation of breeding success may be the result of changes in water levels during the nesting period, but other less known factors (e.g. predation by Black-backed Gulls) are probably at work as well. The total number of Common Merganser broods is very stable from year to year (average 13.4, range 12 to 16).

Trends and Predictions of Acidifying Substances in Eastern North America

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ABSTRACT (VERBAL PRESENTATION)

In an effort to reduce the impact of acidic deposition on sensitive ecosystems, visibility and human health, Canada and the United States have set out to meet goals to reduce the levels of sulphur dioxide (SO₂) and nitrogen oxides (NO_x) emissions in their respective countries.

APPENDIX C: REGIONAL ACIDIFICATION AND LOW-LEVEL OXIDANTS

This presentation will initially examine the temporal trends of acidic compounds in the precipitation of eastern North America for the years 1980 through 1993. Secondly it will discuss the use of a Eulerian model, ADOM (Acid Deposition and Oxidant Model) to predict future trends and will provide an example of its capability using a given scenario.

Intensive Harvesting impacts on Soil Temperature and Soil Chemistry

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ABSTRACT (POSTER PRESENTATION)

Removal of slash from sites due to whole tree harvesting results in a loss of nutrients and leads to rapid decomposition of soil organic matter. It also increases nitrification due to warmer soil temperature, causes increased acidity and loss of base cations from the solum. To investigate these effects a series of lysimeter studies were started in 1989 with three main treatments: Control (C); Conventional Harvest (CH) and Whole Tree Harvest (WTH). Installing lysimeters in select cut (Sel) and skid rows (Skr) were the additional treatments.

Treatment effects were significant on soil temperature. Whole tree harvest has a pronounced effect on diurnal temperature fluctuations in the organic horizon. Treatment effects on daily average temperatures were different in spring and fall. Calculated heat units accumulated in whole tree harvest plots over the growing season were significantly higher than those in the other plots. Treatments affected the concentrations of various nutrients in the leachates. Levels of nitrates and Al were higher in the leachates from skid rows in the whole tree harvest plots than in the others.

ECOLOGICAL EFFECTS OF OXIDANTS

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This presentation will summarize efforts that are currently under way as part of the NOx/VOC Management Plan to re-evaluate the Canadian air quality objectives for ozone, based on vegetation response. The Vegetation Objective Working Group (VOWG) was established with the overall goal/objective being: to review the current state of

APPENDIX C: REGIONAL ACIDIFICATION AND LOW-LEVEL OXIDANTS

knowledge on ozone damage to Canadian vegetation and develop a position on the form and level of an ambient ozone objective to protect vegetation.

The VOWG met for the first time in June 1992, and further clarified its terms of reference as follows:

- to review existing Canadian National Ambient Air Quality Objectives for ozone and make recommendations on their suitability (with respect to protecting vegetation)
- to evaluate available data on ozone damage to field crops, horticultural crops and forestry
- to develop the form and level of an ambient ozone objective to protect vegetation
- if necessary, to make recommendations for additional research required to develop the objective

Prior to the establishment of the VOWG in early 1992, another similar work group consisting of vegetation experts from across Canada and the United States had been assembled in October, 1989. This WG, referred to as the VOC/NO_x/O₃ Impacts Expert Work Group - Vegetation Component, met in October 1989. The purpose of the WG was to undertake an assessment of the 7-hour growing season objective proposed by the Federal/Provincial Advisory Committee on Air Quality and to make recommendations regarding an appropriate objective for the protection of vegetation.

As required by the NO_x/VOC consultation process, the recommendations of this WG were presented in December 1989. The following conclusions were reached:

1. The proposed 7-hour based, June-August growing season mean for ozone of 32 ppb is inappropriate as a Canadian air quality objective.
2. A different type of biologically-based, long-term measure of exposure for vegetation is required, which reflects more accurately the dynamics of ozone exposure and plant response.
3. For the purpose of the NO_x/VOCE management plan, the 82 ppb 1-hour objective is reasonable, although it may not protect some sensitive plant species or ecosystems.
4. The air quality data bases for ozone, Nix, and VOCs are woefully inadequate for non-urban regions of the country at the sites of agricultural, forest and natural ecosystems at risk.

APPENDIX C: REGIONAL ACIDIFICATION AND LOW-LEVEL OXIDANTS

As a follow-up to these recommendations, an ozone/vegetation effects workshop, sponsored by the Canadian Institute for Research in Atmospheric Chemistry (CIRAC) was held in February 1991. This workshop also served as a forum for discussion of a research proposal which had been developed by Drs. A. Legge (then of Alberta Research Council) and S. Krupa (University of Minnesota), under contract to the Atmospheric Environment Service (AES), Environment Canada.

Specifically, the workshop focused three main questions and developed responses as follows:

- 1. Is the current 1-hour air quality objective for ozone of 82 ppb scientifically defensible?**

Based on the information available in the literature (primarily foliar response data), the answer was a "no" at this time.

- 2. Does the 1-hour air quality objective for ozone provide protection for known sensitive crop species against acute injury or against effects on yield and productivity?**

A clear answer to this was not possible, because it is known that acute injury may or may not have an effect on yield and productivity.

- 3. Can there be a single, scientifically defensible national ambient air quality objective for ozone?**

The answer to this question was "yes", but it would require a more environmentally encompassing approach to derive a new air quality objective for ozone. This is due to the fact that different regions of Canada differ in their climate, ozone exposure characteristics, duration of the plant growth season and in the types of crops grown and their sensitivity to ozone.

The contract to the Alberta Research Council to explore these issues consisted of a retrospective analysis of the available international data on crop response to ozone exposure via open-top chambers with and without charcoal filtration, and commenced in July 1992.

The initial findings of the NCLAN assessment revealed that the number of stations with scientifically valid data for this type of dose:response assessment were small relative to the total project. However, there were sufficient data to undertake a modified version of the statistical analysis that was proposed. The results of this assessment, in which ozone frequency distributions for valid effects and no-effects cases were statistically compared, to identify the thresholds where these exposure profiles began to depart, indicated that the critical concentrations of ozone exposure in terms of crop response, lie somewhere in the range of 50-87 ppb.

APPENDIX C: REGIONAL ACIDIFICATION AND LOW-LEVEL OXIDANTS

In an effort to further explore this finding, an additional contract was let to undertake an analysis of the European Open Top Chamber Program. This contract commenced in February 1994 and was finalized in November 1995. The conclusions reached indicated that frequency distributions between effect and no effect European cases separated at levels greater than about 35 ppb. The second phase also provided additional material to the VOWG on which to address concerns raised in the scientific literature regarding the importance of short term peak concentrations vs. lower, mid-range concentrations.

At its October 1995 meeting, the VOWG considered a number of directions and possibilities for completing the assigned task. These included an analysis of cumulative exposure indices developed in both Europe and the US. These include the AOT40 (Accumulated Exposure over a Threshold Concentration) and the SUM06 indices. The results of this analysis are not yet complete; however, some of the initial data analysis is presented and discussed as it relates to ambient ozone levels in the Atlantic Provinces relative to other Canadian provinces and US States.

The Canadian NO_x/VOC Science Program: A Tool for Policy Development

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ABSTRACT (POSTER PRESENTATION)

Growing public concern during the 1980s resulted in the Canadian Council of Ministers of the Environment adopting the Management Plan for NO_x and VOCs. As well as satisfying domestic ground-level ozone requirements to meet the 82 ppb one hour air quality objective, the Plan addresses requirements for Canada to meet UN ECE NO_x and VOC protocol reductions. The NO_x/VOC Science Program is a key element of the Plan which will assess the current state of knowledge associated with ground-level ozone formation and control in Canada. It will enable Federal and Provincial governments to establish effective NO_x and VOC controls. The NO_x/VOC Science Program is organized in a multistakeholder framework incorporating expertise and input from all levels of government, industry, academia and public interest groups.

The modelling aspect of the Program consists of the development and evaluation of models for three regions of Canada for which ground-level ozone is a problem: the Lower Fraser Valley of British Columbia, the Windsor - Quebec City Corridor of southern Ontario and Quebec, and the Southern Atlantic Region. The models being evaluated and applied for selected emission reduction scenarios are as follows:

APPENDIX C: REGIONAL ACIDIFICATION AND LOW-LEVEL OXIDANTS

- Mesoscale Compressible Community Model / Acid Deposition and Oxidant Model,
- Atmospheric Environment Service / Lagrangian Oxidant Model (based on ADOM)
- GEsthacht Simulation Model of the Atmosphere / Acid Deposition and Oxidant Model (Ontario only), and the
- Colorado State University / Regional Atmospheric Modelling System - Urban Airshed Model V (British Columbia only).

The status of emission inventory information and its suitability for supporting model development and scenario evaluation will be presented. The interim evaluation and scenario results for the above models will be presented, along with preliminary estimates of the magnitude of NO_x and VOC emission reductions required to reduce ground-level ozone concentrations for severe episodic conditions. The Eulerian ADOM models typically underpredict ozone maxima by 5-8 ppb, while the Lagrangian formulation tends to overpredict by about 6 ppb. RMS errors for ozone are of the order of 20-25 ppb (similar to the uncertainty in the observed ozone data analysis). The impact of long range transport of NO_x, VOCs and ozone can be significant in eastern Canada, and is illustrated in the modelling results.

Parallel to the modelling effort is the analysis of the ambient ozone, NO_x and VOC data collected over the past fifteen years. A brief summary of ambient trends and episode characteristics will be provided.

Health Effects of Oxidants

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ABSTRACT (VERBAL PRESENTATION)

Airborne oxidants, particularly ground-level ozone, represent an important air pollution issue in a number of regions of Canada, including the southern Atlantic Region. There is a large body of scientific evidence on the health effects of ozone, including animal studies, studies of humans in controlled exposure chambers, follow-up studies on panels of children and adults, and large-scale studies using administrative data on death and hospital admissions in relation to ambient ozone levels. This evidence indicates that the health effects of ozone at levels that occur in Canada include lung inflammation, reduced lung function, airway hyperreactivity, respiratory symptoms, possible increased medication use and physician visits, increased emergency department visits, reduced exercise capacity, increased hospital admissions and possible increased mortality. Areas requiring further investigation include the relationship

APPENDIX C: REGIONAL ACIDIFICATION AND LOW-LEVEL OXIDANTS

between mechanistic effects (eg. inflammation), and measurable clinical effects, clearer delineation of susceptible populations, effects of long term exposure, and determination of the relative importance of ozone relative to other triggers in aggravating pre-existing disease. Implications of the scientific evidence include determining appropriate means to protect the most sensitive individuals, and weighing the costs and benefits of regulatory and other control activities.

Ground - Level Ozone Climatology in the Maritimes

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ABSTRACT (POSTER PRESENTATION)

The Southern Atlantic Region (SAR) is one of the three areas in Canada which experiences frequent concentrations of ground-level ozone in excess of the one-hour maximum acceptable air quality objective of 82 parts per billion (ppb). Ground-level ozone is measured at 13 sites in the Maritimes; some of these sites have measurements since 1980. This poster looks at some of the seasonal variations and trends such as those found in day of the week and time of the day of ground-level ozone exceedances at Maritime sites. The meteorology associated with ground-level ozone exceedances in the Maritimes is described in the poster.

Are Rising Water Temperatures the Root Cause of Higher pH Levels in Nova Scotia Rivers?

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ABSTRACT (POSTER PRESENTATION)

Water chemistry data from DFO's LRTAP Biomonitoring Program in Nova Scotia salmon rivers show increases in mean annual pH and ANC over the period 1981-1991, and rising juvenile salmon numbers at sites where acid toxicity is borderline (near pH 5). Over this same period there was also a significant increase in mean annual river water temperatures, a decline in DOC and no significant trend in sulphate levels. The tentative conclusion was that temperatures were controlling DOC levels and DOC levels (organic acids) were in turn controlling pH.

APPENDIX C: REGIONAL ACIDIFICATION AND LOW-LEVEL OXIDANTS

The eruption of Mt. Pinatubo in June, 1991, and the resulting global climatic perturbation has provided a test of this hypothesis. The years 1992 and 1993 were the two coldest since the river monitoring program began in 1981, and the two lowest pH (and ANC) years were 1993 and 1994. Ion balance indicates that the low pH levels were primarily caused by an increase in organic acids.

Biomass growth is usually limited by the availability of light and nutrients, while decomposition is limited by temperature. This mechanism is the cause of peat bogs, among other things. The low temperatures of 1992-93 would have caused a higher accumulation of undecomposed organic matter in the soils and bogs, and the subsequent leaching led to higher levels of organic acids in rivers during 1993-94. Water temperatures recovered during 1994 and a complete chemical recovery is expected in 1995.

However, the water temperature hypothesis now has a rival in that sulphate levels over the 1981-94 period are now showing a statistically significant decline. Is the decline in sulphate also temperature related?

APPENDIX D

ABSTRACTS AND SUMMARIES

(IN ALPHABETICAL ORDER BY AUTHOR)

VERBAL AND POSTER PRESENTATIONS FOR DAY TWO

WEDNESDAY 29 NOVEMBER 1995

STRATOSPHERIC OZONE DEPLETION

AND

HAZARDOUS AIR POLLUTANTS

APPENDIX D: STRATOSPHERIC OZONE DEPLETION AND HAZARDOUS AIR POLLUTANTS

Decline in Total Column Ozone in the Atlantic Provinces Since 1980

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ABSTRACT (POSTER PRESENTATION)

As part of a nation-wide research and "Ozone Watch" monitoring program, Environment Canada monitors total column ozone on a daily basis using ground-based instruments (Brewer spectrophotometers) located at two sites in the Atlantic provinces, Bedford, N.S. (near Halifax) and Goose Bay, Labrador. The condition of the ozone layer over these two sites in recent years was compared to pre-1980 conditions.

Because anthropogenically-induced ozone layer depletion began to affect Canadian sites in about 1980, pre-1980 average daily measurements of the amount of ozone in a column extending from the instrument to the top of the atmosphere were assumed to represent the normal climatological condition of the ozone layer at each site. Because ozone layer measurements only began at Bedford in 1992, it was necessary to use a proxy climatology (based on satellite observations and data from other long-term ground stations) to represent pre-1980 conditions. At Bedford in 1993, large negative departures from normal conditions were experienced, especially in the winter and spring months, with some daily departures of more than 30% below normal. Monthly average depletions of 12 to 15% occurred from January through May. Total column ozone averaged about 7% below normal for the year. This pattern of depletion also occurred at Goose Bay and other Canadian sites. Since ozone destruction occurs on sulphate aerosols injected into the stratosphere by major volcanic eruptions, the large depletion observed during 1993 in Canada, and indeed on a global basis, was quantitatively consistent with the occurrence of sulphate aerosols in the stratosphere from the 1991 eruption of Mount Pinatubo.

Environment Canada has been monitoring the ozone layer at Goose Bay, Labrador, since 1962. A recent study (Tarasick, D.W., 1995: *Ozone Climatology and Trends at Canadian Stations*, Atmospheric Environment Service Internal Report, Environment Canada, Downsview Ontario M3H 5T4) calculated the yearly average deviations of total column ozone from pre-1980 values at Goose Bay and found a statistically-significant (at the 95% level) best-fit linear decrease of $0.50 \pm 0.27\%$ per year for the period 1980-1994, even after excluding 1993 (as it may have been affected by aerosols from the eruption of Mt. Pinatubo). Similar reductions have occurred at other mid-latitude sites. This trend to lower values since 1980 is likely due to a number of anthropogenic and natural mechanisms.

Concentrations of stratospheric chlorine derived from anthropogenic chlorofluorocarbons (CFCs), which are major ozone depleting substances (ODSs), are expected to increase until the end of the century, but then begin to decline due to the international control measures of the Montreal Protocol and its amendments. Therefore, depletions will likely increase over the next few years, with accompanying ultraviolet radiation increases, with recovery not expected until the middle of the next century (or

APPENDIX D: STRATOSPHERIC OZONE DEPLETION AND HAZARDOUS AIR POLLUTANTS

later, if ODS phase-out regulations are not adhered to). Therefore, monitoring of the ozone layer and stratospheric conditions to determine the progress of control measures, and research and modelling to clarify the causes of ozone layer depletion should continue to be important functions of the Canadian science program well into the next century.

The Canadian "UV Index"TM Program and UV-B Measurements at Bedford, Nova Scotia

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ABSTRACT (POSTER PRESENTATION)

In an effort to inform and educate Canadians about ultraviolet (UV) radiation, Environment Canada, in consultation with Health Canada and other health organizations, developed and launched the UV Index program in the spring of 1992. In so doing, Canada became the first country to provide a daily forecast program of UV radiation levels. The daily forecast is based on the angle of the sun at solar noon, the forecast amount of ozone overhead and the predicted amount of cloud over the site in question. The chief goal of the forecast program is to provide a means for the public to make daily decisions about the appropriate levels of sun protection. Therefore, general advice on sun exposure is provided as part of the program. Specific sun protection actions will be recommended when they become available from the health agencies.

The Environment Canada UV Index is a measure of the intensity of ultraviolet radiation weighted according to the Diffey erythemal action spectrum to mimic the way human tissue responds to UV radiation. The intensity is then divided by 25 milliwatts per square metre to produce an index. The UV Index generally ranges from 0 to 10 in Canada, although values may approach 14 in the tropics.

Atlantic Canada receives less ultraviolet radiation than more southerly locations. For example, the clear-sky daily maximum UV Index climatology for Bedford, N.S., derived from an empirical relationship between surface UV flux and the two main factors that determine this flux (solar angle and the pre-1980 total column ozone climatology) has a bell-shaped curve with a maximum of about 7.5 around July 1 and a minimum of less than one around January 1. The pre-1980 period was used to represent conditions prior to anthropogenically-induced ozone layer depletion. Goose Bay, Labrador, has a similar curve, with a lower summer maximum of just over 6, due to its more northerly location.

Large changes occur in daily total column ozone measurements as a result of meteorological variability, such as changes in wind and pressure patterns, tropospheric and stratospheric temperatures and tropopause height. Daily maximum UV Index measurements at Bedford, although strongly controlled by the time of year, are affected

APPENDIX D: STRATOSPHERIC OZONE DEPLETION AND HAZARDOUS AIR POLLUTANTS

by these short-term ozone layer changes, by longer-term ozone layer depletion, and by clouds, precipitation and atmospheric pollution. In 1993 at Bedford, total column ozone averaged 7% below normal for the year. UV measurements well above normal were associated with periods of lower than normal ozone thickness that occurred during the first two-thirds of the year. The highest UV Index measurement in 1993 was 9.7 on July 12, which was about 30% above normal for that date. The column of ozone above Bedford that day was 12% below normal. This represents an enhancement factor of 2.5.

Ozone layer depletion is expected to continue to worsen over the next few years, with accompanying UV increases, and recovery is not expected until the middle of the next century. Since UV is dangerous to living organisms, monitoring of UV, informing the public of expected UV levels, and research into the impacts of UV should all continue to be high priority activities well into the next century.

Effects of UV-B Radiation on Grass Morphogenesis

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ABSTRACT (POSTER PRESENTATION)

The effect of excluding ultraviolet-B (UV-B) radiation on morphogenetic processes of timothy (*Phleum pratense* L.) was studied under field conditions using a UV-B exclusion system. Specific leaf area (SLA), the proportion of leaf blades in the above-ground biomass (LWR) and the number of tillers per plant were measured twice in the seedling year of 1994 under current levels of UV-B (cellulose diacetate covering) and without UV-B (polyester covering). Leaf elongation rates (LER) and leaf appearance rates (LAR) were also measured in the first 20 days of two regrowth cycles. Removing UV-B had a positive effect of LER during the second regrowth but had no effect during the first regrowth. The number of tillers per plant was greater when UV-B was excluded. Removing UV-B had no effect on LAR, LWR and SLA. These results suggest that timothy morphogenetic processes such as leaf elongation and tillering are affected by UV-B radiation. Further field studies are required to confirm those preliminary findings.

APPENDIX D: STRATOSPHERIC OZONE DEPLETION AND HAZARDOUS AIR POLLUTANTS

Trace Organic Contaminants in Wet Precipitation of Atlantic Canada

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ABSTRACT (POSTER PRESENTATION)

Wet precipitation samples have been collected on a monthly basis from four locations in Atlantic Canada since 1980. Samples were analyzed for organochlorine pesticides, triazine herbicides, chlorinated phenols, polychlorinated biphenyls (PCBs), chlorinated benzenes and polyaromatic hydrocarbons (PAHs).

The compounds most commonly found included the pesticide lindane (γ -HCH) and its decomposition product α -HCH, fluoranthene, and PCBs. Statistical analysis indicates a significant decrease in concentration for γ -HCH and α -HCH after 1983. Seasonal patterns were observed with maximum concentrations/loadings occurring during the spring and fall.

Fluoranthene and other PAHs were shown to follow seasonal patterns, with increasing concentrations during the colder months of the year (December to April). Spatial influences were also observed, suggesting both localized and long-range atmospheric source inputs.

Abnormally high annual mean concentrations of PCBs ranging between non-detectable levels and 0.22 $\mu\text{g/L}$ were measured during the 1981-1986 period at the PEI site. Spatial variations for PCBs in the Atlantic Region were significant and attributed in part to local source inputs. Seasonal patterns similar to the PAHs were also observed. Concentrations dropped to non-detectable levels after 1984 at all sites with the exception of a few sporadic observations.

**Growth and Physiological Responses of Four Broccoli Cultivars
to Ambient and Reduced Levels of UV-B Radiation During Two Seasons**

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ABSTRACT (POSTER PRESENTATION)

Using field greenhouses which protected all plants within from direct sunlight, four cvs of broccoli were grown under polyester (screens light <315 nm) or cellulose diacetate (transmits all light) plastic. These plants were compared with others grown in full ambient light. Broccoli seedlings (cvs Cruiser, Emperor, Paragon, Pinnacle) were started in the greenhouse and transplanted to the field plots in mid to late June. Eight plants of one cv were placed in each 0.5-m row. Moisture was provided with sub-surface irrigation which maintained root water levels within 30% of the upper limit for the growing season. The two growing seasons were quite different with 1994 producing plants that were about 40% less weight/plant than in 1993. The amount of extractable chlorophyll and measured photosynthesis were generally not different for the 2 years, although the cultivars appear to be consistently different from one another. There were no consistent trends between treatments as some cultivars appeared to show a consistent response to level of UV-B while others did not. The level of UV-B absorbing flavonoids was about 150% greater in 1994 than in 1993. The flavonoid levels in full ambient sunlight were also greater than those in the greenhouses. These differences could be attributed to the lower level of UV-B light due to shading by the structure (20 to 40%). The differences between the crop years appears to be due to stresses other than UV-B that had an effect of flavonoid synthesis as well as plant yield. The responses to increased levels of UV-B under the three treatments were close to the expected, however it was also evident that there is some difference in response related to cultivar.

APPENDIX D: STRATOSPHERIC OZONE DEPLETION AND HAZARDOUS AIR POLLUTANTS

Quantifying the Potential Effects of Ozone Depletion on Aquatic Systems

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ABSTRACT (VERBAL PRESENTATION)

Increases in ultraviolet-B radiation (UV-B, 280 - 320 nm) associated with stratospheric ozone depletion are expected to affect many biological and photochemical processes in aquatic systems. Potential changes are commonly quantified with an amplification factor that relates incremental effects of UVB to incremental change in stratospheric ozone. When aquatic processes are considered, amplification factors depend not only on the spectral sensitivity (action spectrum) of the target process, but also on the depth ranges and time scales that are assumed to be relevant. As an example, we present amplification factors for the inhibition of water column photosynthesis under the Antarctic ozone hole during a field study in the austral spring of 1993. Sensitivity analysis shows that inhibition of photosynthesis by UV (280 - 400 nm), as well as the incremental effects of ozone depletion, depend strongly on the depth of vertical mixing and the relative sensitivity of phytoplankton assemblages to UV. Both varied greatly during the study. The analysis demonstrates that hydrographic and physiological variability should be considered when assessing the potential effects of ozone depletion on a biological process.

Toxic Substances Assessment and Management Processes Used by Environment Canada

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ABSTRACT (VERBAL PRESENTATION)

Assessing and controlling the environmental effects of toxic substances presently has a high priority within Environment Canada. The Department conducts a number of activities under the authority of the Canadian Environmental Protection Act (CEPA) which attempt to identify substances which may be toxic, assess their hazard and where necessary apply life cycle management to reduce or prevent harm. The New Substances Notification Regulation gives the Department authority to request information on the potential negative effects of any substance prior to its commercial introduction to Canada. Under the Priority Substance List Assessment Program,

APPENDIX D: STRATOSPHERIC OZONE DEPLETION AND HAZARDOUS AIR POLLUTANTS

existing commercial substances are evaluated on a priority basis to determine whether controls are required to reduce or eliminate environmental risks. Finally, the Toxic Substances Management Policy establishes the principles which direct the federal government to control or eliminate substances on the basis of their persistence, bioaccumulative potential and toxic characteristics.

A UV-B Radiation Exclusion System and a Note of Caution

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ABSTRACT (POSTER PRESENTATION)

Studies assessing the effects of ultraviolet-B (290-315 nm) radiation on crop production have involved partially controlled environments that focus on increased levels of UV-B radiation. Few studies have examined the effects of current UV-B levels on growing plants in the field in comparison to environments with reduced UV-B. This study was conducted in Nappan, Nova Scotia and involved the testing of a UV-B exclusion system consisting of open-ended wooden frames covered with a series of panels of either polyester (absorbs UV-B < 315 nm) or cellulose acetate (absorbs UV-B < 292 nm). Plots were established under each plastic as well as under the ambient environment. Measurements of net radiation, air temperature and biologically effective UV-B radiation under each filter and in the ambient environment were performed. Temperature effects throughout all plots were slight, differing on average by < 0.2C over three complete seasons. The shading effects on radiation were more pronounced. Daytime net radiation was 20 to 33% lower under both plastics than the outside environment. Greater differences were observed in UV-B radiation under the cellulose acetate shelter compared to ambient UV-B intensities which were reduced by 45%.

APPENDIX D: STRATOSPHERIC OZONE DEPLETION AND HAZARDOUS AIR POLLUTANTS

National/Regional Policy Initiatives and Control Strategies for Ozone Depleting Substances and Hazardous Air Pollutants

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INTRODUCTION

The workshop organizers have presented me with an interesting opportunity to discuss policy initiatives and control strategies for two air issues which are very different in their level of activity and understanding. The protection of the ozone layer (ozone depleting substances) is considered to be a mature issue relative to hazardous air pollutants issue which is still being defined in Canada, as well as in most other countries and jurisdictions. In this presentation, I will provide you with a very brief overview of the two issues with emphasis on federal actions and programs, with comments on relevant activities in Atlantic Canada. As with many of the air issues, because of their nature, are being driven by international and global concerns and activities.

OZONE DEPLETING SUBSTANCES

International activities:

Concerns relating to the damage of the ozone layer as the result of CFCs, was brought to the attention of the international community in the early 1970s. It was recognized that the protection of the ozone layer was a global problem requiring international cooperation and action. The United Nations Environmental Program began assessing the scientific information and policy implications in 1977. In 1985, the Vienna Convention for the Protection of the Ozone Layer was signed and focused on cooperative research, data exchange and regulatory measures. As a result of the Vienna Convention, the Montreal Protocol was developed and signed in 1987. The Montreal Protocol is an international agreement, with 148 signatories, to protect the ozone layer by reducing the release of ODS into the atmosphere and ultimate goal of eliminating ODS consumption world-wide. Since 1987, there have been two amendments to the Protocol - the London Amendment (1990) and the Copenhagen Amendment (1992), which accelerated the phase out measures for ODS and added HCFCs, methyl bromide and HBFCs. In early December 1995, discussions will be held in Vienna to focus on measures and an accelerated phase-out schedule for HCFCs and methyl bromide. An overview of the history of key developments related to ozone depleting substances is provided in Table 1.

APPENDIX D: STRATOSPHERIC OZONE DEPLETION AND HAZARDOUS AIR POLLUTANTS

On the national scene

Canada has been and continues to be very supportive and proactive regarding the protection of the ozone layer. The federal government has put in place both regulatory and non-regulatory initiatives to reduce the release of ozone-depleting substances to the atmosphere. Beginning in 1980, the federal government started to control CFCs by banning their use as propellant in aerosols. There are currently two federal regulations, the Ozone-depleting Substances (ODS) Regulations and the Ozone-depleting Substances Products (ODSP) Regulations under the Canadian Environmental Protection Act. By 1993, the Canadian programs, including provincial actions, resulted in a 77% reduction of Canadian annual consumption of CFCs from 1986, the base year of the Montreal Protocol.

The federal government is presently amending the ODS Regulations to incorporate controls for hydrochlorofluorocarbons (HCFC). Canada's position is the complete phase-out of HCFCs by 2020. HCFCs are viewed as transitional substitutes to other ODS substance if there are no other technically or economically feasible alternatives. Non-recoverables uses will be banned in 2020. Environment Canada has also initiated the development of an ODS release regulation for application to federal government operations and facilities.

A summary of Canada's ODS Phase-out Policies are listed in Table 2.

There have also been a number of non-regulatory activities undertaken in cooperation with the provinces and industry, such as; the "National Action Plan the Recovery, Recycling and Reclamation of CFCs" and training programs on the "Code of Practice for the Reduction of CFC Emissions from the Refrigeration and Air Conditioning Systems".

The federal government is further strengthening its program in terms of the phase out of ODS where feasible, minimizing releases, supporting new technologies and alternatives, and a program for the accelerated phase-out of HCFCs. This program was developed based on consultations with stakeholders across Canada and the key elements are summarized in Table 3.

Regional activities

From a policy perspective, the national programs are closely linked to international commitments and coordinated by Environment Canada, Headquarters. The regional role has focused on five areas;

- Implementation of the ODS and ODSP Regulations,
- Compliance promotion and education (with emphasis on federal operations),
- UV-B levels monitoring and public advisories,
- Working with the provinces and municipalities to harmonize programs, and
- Providing technical advice and feedback to Headquarters on proposed regulations and non-regulatory activities.

APPENDIX D: STRATOSPHERIC OZONE DEPLETION AND HAZARDOUS AIR POLLUTANTS

Recently, much of our regional activity has been devoted to the export and import of ODS between the US and Canada, as well as via our ports in Atlantic Canada, in cooperation with Customs Canada.

HAZARDOUS AIR POLLUTANTS

Relative to the stratospheric ozone layer issue, hazardous air pollutants (HAPs) is considered a new and emerging issue in Canada as well as other jurisdictions. From an international perspective, the main concerns related to HAPs are those substances susceptible to long-range transport, with emphasis on persistent organic pollutants (POPs) and heavy metals.

In Canada, the primary concerns relate to the contamination of the Arctic food supply and a significant percentage of the loading to the Great Lakes basin, and in general a lack of understanding of the extent of HAPs pollution. Regionally, there is a high level of interest in the transport and deposition of mercury and its impact on aquatic and other ecosystems.

Even the definition of HAPs is still under discussion, but in domestic discussions the OECD definition has been used, which defines HAPs as;

" Gaseous, aerosol or particulate contaminants present in the ambient air in trace amounts with characteristics (toxicity, persistence) so as to be hazardous to human health or plant or animal life."

International initiatives:

There are a number of United Nations (UN) driven initiatives underway in response to concerns regarding POPs and heavy metals, which are briefly described below:

► UN Economic Commission for Europe (UN ECE)

The recommendation to proceed with the development of POPs and heavy metals Protocols under the LRTAP Convention was given to the Executive Body of the UN ECE in August 1995. It is anticipated that the Executive Body will accept this recommendation and the initial negotiating sessions for the Protocols will be held in February 1996. The protocols will focus on sixteen POPs (Table 4) and three heavy metals ie. mercury, lead and cadmium. Canada will be leading the POPs negotiations. It is expected that the Protocols will come into effect after the year 2000, with the first targets for reductions by 2005.

APPENDIX D: STRATOSPHERIC OZONE DEPLETION AND HAZARDOUS AIR POLLUTANTS

► Global Strategy for POPs - UN Environmental Program (UNEP)

In May 1995, the UNEP Governing Council decided that a global strategy for managing POPs should be prepared by early 1996. The Intergovernmental Forum on Chemical Safety (IFCS) was identified as the international group to prepare the draft strategy. As a first step, the IFCS in cooperation with the World Health Organization developed profiles for selected POPs (12 substances) listed in Table 5. This background work was presented to the Washington Conference on Land-Based Sources of Marine Pollution in late October 1995.

► Global Programmes of Action for POPs and Heavy Metals under Agenda 21 (UNCED) on Land-Based Sources of Marine Pollution

At the Washington Conference, it was agreed that a global legally binding instrument should be developed for the management of POPs. The UNEP POPs list (Table 5) was adopted as action list on a global scale. There was, however, no agreement on the need to develop a global strategy for heavy metals. Although, there was a commitment by all parties to prepare national action plans for POPs and heavy metals by 1998.

Continental initiatives:

There are also a number of North American initiatives that will have an impact on HAPs issues in Canada noted below:

► NAFTA Commission for Environmental Cooperation (CEC) - Resolution on the Safe Management of Chemicals

In October 1995, the United States, Canada and Mexico signed a Resolution on the Safe Management of Chemicals in the North American context. The Resolution established a trilateral steering committee to initiate action to reduce Persistent Toxic Substances (PTSs). The initial PTSs list includes the UNEP POPs list plus UN ECE metals. The final selection of priority substances for reduction are under development and should be completed by February 1996.

► Implementation of Annex 15, Great Lakes Water Quality Agreement

Annex 15 under the Canada/US Great Lakes Water Quality Agreement relates to airborne toxic substances, and includes provisions for monitoring and scientific efforts to identify PTSs of concern entering the Great Lakes Basin via the air pathway. In addition, there was a commitment to reduce or eliminate PTSs entering the basin. Eight years after signing the Agreement, there is still no good overview of the concerns or progress in the reduction or elimination of PTSs in the Great Lakes Basin.

APPENDIX D: STRATOSPHERIC OZONE DEPLETION AND HAZARDOUS AIR POLLUTANTS

► Binational Virtual Elimination Strategy for PTSs Affecting the Great Lakes

In February 1995, Canada and the United States agreed that a strategy would be developed by February 1996 to address the most persistent toxic substances in the Great Lakes environment. A draft strategy was developed in August 1995 and as shown in Table 6, the strategy contains Level I and Level II lists for PTSs targeted for reduction or elimination. This strategy will accelerate action under Annex 15 of the Great Lakes Water Quality Agreement. Reductions in the Great Lakes Basin will be addressed under the current Lakeside Management Plans, whereas this strategy will focus on sources outside the Great Lakes Basin in Canada and the continental United States.

► Canada/United States Air Quality Agreement

In the future, the Canada/US Air Quality Agreement may be used as a mechanism for bilateral commitments to manage POPs and heavy metals.

A HAPS Strategy for Canada:

In April 1996, a multistakeholder workshop was held under the auspices of the HAPS Task Group of the National Air Issues Coordinating Committee. The workshop participants indicated that existing tools are probably adequate, and urged that approaches should build on existing mechanisms (eg. the Federal Toxic Substance Management Policy) to manage HAPS in Canada. The participants also agreed that there is a need to:

- establish a mechanism to set priorities and research needs,
- link to other air issues.

The provinces expressed concern that the national strategy may be driven by international commitments rather than national priorities.

In response to the workshop outputs, the HAPs Task Group developed a work plan and the first step is to review existing programs across Canada before proceeding with the development of a national strategy. This work is underway under contract. The HAPs Task Group has an important consultative role in coordinating provincial/other stakeholders input to a national strategy as well as Canada's international negotiating positions.

Canada's activities and programs to address the control of toxic substances at the Federal level will be addressed in W. Ernst's presentation on the Canadian Environmental Protection Act (CEPA).

APPENDIX D: STRATOSPHERIC OZONE DEPLETION AND HAZARDOUS AIR POLLUTANTS

Regional activities

The regional role relative to HAPs is the following;

- Implementation of CEPA emissions and fuels regulations for HAPs,
- Definition of regional concerns and problems ie. monitoring for PAHs, mercury and organics,
- Provision of Technical assistance to Headquarters eg. chair the national Issue Table for Electric Power Generation related to CEPA toxics under the Strategic Options Process,
- Involvement in international cooperative programs ie. international mercury workshop, Gulf of Maine Council activities, etc.

SUMMARY

The protection of the stratospheric ozone layer is a mature issue in Canada. The next steps for the Canadian activities will focus on technology improvements, development of ODS alternatives and the promotion of the phase-out of ODS as soon as feasible. Canada will continue its active role in international and global discussions on this issue.

In regard to HAPs, this is an emerging issue at the global, international, continental and national levels and will focus on POPs and heavy metals. Canada has much to gain from these global and international activities since many of Canada's concerns relate to the global and regional transboundary movements of HAPs. Many of the international substances of concern have already been banned or are being addressed under federal initiatives such as the Toxic Substances Management Policy. However, much needs to be done in defining problems and in developing a coordinated strategy to address HAPs in Canada.

Acknowledgements

I wish to gratefully acknowledge James Bamwoya of Environment Canada, Atlantic Region and Wayne Draper and Sheila Jones of Environment Canada, Headquarters for their contributions on stratospheric ozone and hazardous air pollutants, respectively, in the preparation of this paper.

Aquatic Photochemistry and Biological Carbon Utilization

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ABSTRACT (POSTER PRESENTATION)

The cycling of dissolved organic matter (DOM) in the ocean has received much attention in efforts to understand the processes which explain chemical and biological reactivity in a manner consistent with observed molecular weight and age distributions of DOM in the ocean. Photochemistry has been suggested as an important process in the cycling of DOM through both direct oxidation and alteration of its bioavailability. In this study we have investigated directly the link between photochemical and biological transformations of DOM from a salt marsh on Sapelo Island, GA. Seawater with and without added isolated humic material showed typical microbial consumption of DOM as monitored with tritiated leucine uptake, bacterial counts in grazer-free incubations, and direct measurements of DOM via high temperature combustion. Alternating cycles of light exposure and microbial degradation resulted in 2 to 3 times more complete degradation of bulk DOM and the humic substances fraction of DOM than did microbial degradation (dark incubations) alone, due both to direct losses of photochemical products and to enhanced microbial decomposition of the remaining DOM following light exposure. Direct measurements of dissolved inorganic carbon (DIC) and carbon monoxide (CO) in 0.2 μ m filtered, irradiated seawater showed DIC to be the dominant photochemical product (at least 15 times larger than CO on a carbon basis) and to represent a significant direct loss of DOM in coastal waters. When normalized to optical properties, water from all treatments showed remarkable consistency in DIC and CO photo production rates. Using direct measures of DIC, CO, DOM, and microbial carbon incorporation, it seems that increased microbial production depends largely on photochemically mediated changes in the refractory nature of residual humic material and not solely on the production of "consumable" low molecular weight organic compounds. It is clear from these results that increased UV radiation from stratospheric ozone depletion has the potential to significantly alter the rates and pathways of DOM degradation in surface waters.

APPENDIX D: STRATOSPHERIC OZONE DEPLETION AND HAZARDOUS AIR POLLUTANTS

Preliminary Data on the Effects of UV-B Radiation on Motile Behaviour of a Freshwater Diatom, *Nitzschia linearis* (Agardh ex. W. Smith) Smith

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ABSTRACT (POSTER PRESENTATION)

Depletion of the stratospheric ozone layer has been of increased concern due to the correlated increases in ambient ultraviolet radiation. Autotrophic and heterotrophic protists such as dinoflagellates, diatoms, and cryptomonads exposed to higher doses of UV-B (280-320 nm) have demonstrated decreases in pigmentation, photosynthetic rate, photo-orientation and motility; all of which are deleterious to cell survival. The present research investigated the diel response of motile behaviour of *N. linearis* in both natural (freshwater stream) and experimental conditions. Motile behaviour is classified as the percent of moving, non-moving and oscillating cells, as well as the reversal index exhibited by moving cells. The experimental conditions were of simultaneous exposure to either daytime average net radiation or artificial UV-B (UVB-313 fluorescent bulbs manufactured by QPANEL) enhanced ambient levels, in the greenhouse of the Agriculture Canada Experimental Farm, Nappan, NS. UV-B for the control condition was filtered out using polyester filters; UV-B treated cells were irradiated through cellulose diacetate filters. Using the Caldwell weighting spectra, UV-B levels were augmented to 33% (290 mW/sq. metre) and 66% (365 mW/sq. metre) above ambient levels (220 mW/sq. metre). Ambient levels were measured on a clear day of the summer solstice. Daytime average net radiation during experimentation did not exceed 130 W/sq. metre/day (an overcast day). The motile behaviour of cells was examined every two consecutive hours from dawn to dusk, for a total exposure time of 12 hours. Percent motility from the stream indicates that natural gliding behaviour is consistent throughout the day. Percent motility differs significantly between control and treatment conditions with both irradiance levels, at each recording interval. Analysis of experimental motility throughout the day suggests significant differences in moving and non-moving cells; oscillating cells did not significantly change. The reversal index, investigated as both mean reversal per cell and the proportion of gliding cells exhibiting this phenomenon, indicated that no differences occurred due to UV-B exposure at any irradiance level, for any length of time. To conclude, enhanced UV-B levels significantly affect the percent of moving and non-moving cells.

APPENDIX D: STRATOSPHERIC OZONE DEPLETION AND HAZARDOUS AIR POLLUTANTS

Impact of Current UV-B Radiation on Forage Grass and Legume Production in Northern Latitudes.

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ABSTRACT (POSTER PRESENTATION)

Reduction of ozone in the stratosphere has increased ultraviolet-B (UV-B) radiation at earth's surface. This study was designed to assess the effect of such increase on crop production by comparing seeding year growth of eight varieties from four legume and four grass species during two growing seasons (1993 and 1994) under simulated sward conditions. An exclusion system using cellulose diacetate or polyester covers provided comparable growing conditions for the plants except for the presence or absence of ambient UV-B radiation, respectively. In 1993, herbage yield of both grasses and legumes was lower when ambient UV-B radiation was excluded, but this response was statistically significant only in the first growth period when the UV-B levels were highest. Inter- and intra-specific variations for herbage yield, among species evaluated, exist for resistance to current levels of UV-B radiation. Similar results were obtained in 1994 with two important exceptions during the first growth period: 1) the interaction UV-B treatment species variety was not significant, and 2) UV-B radiation had no effect on herbage yield of grass species. Further field studies are needed to validate the resistance of current perennial forage cultivars to cumulative effect of ambient UV-B radiation in succeeding production years.

APPENDIX D: STRATOSPHERIC OZONE DEPLETION AND HAZARDOUS AIR POLLUTANTS

Effects of Increased Ultraviolet Radiation on Terrestrial Plants.

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ABSTRACT (VERBAL PRESENTATION)

Reduction of ozone in the stratosphere has increased ultraviolet-B (UV-B) radiation (280-320 nm) at earth's surface and is expected to affect biological systems. In the past 20 years, many studies, using primarily artificial environments, showed that the growth of a large number of plant species was reduced. To date, the majority of studies were centred on evaluating the effect of enhanced levels of UV-B radiation on plant growth and productivity. These studies have demonstrated a wide range of sensitivity to elevated levels of UV-B radiation among plant species and cultivated crops. The major conclusion of these studies was that enhanced levels of UV-B radiation adversely affected plant growth and reduced biomass production, but a significant number of varieties and species were not affected. In temperate-latitude crop species inter- and intra-specific variation were shown to exist for resistance to current and enhanced levels of UV-B radiation. Cultivars ranged in sensitivity from highly susceptible to highly tolerant, while in a few species some varieties had increased productivity in response to enhanced UV-B levels under field conditions. More recently, a study conducted in Nova Scotia presented evidence of significant reduction in biomass yield of grass and legume species when solar UV-B radiation was filtered out. Collectively, the results of these studies suggest that the current ambient levels of UV-B radiation in northern latitudes may be beneficial to crop growth and productivity. Further long-term field studies are needed to validate the above conclusion and assess the cumulative effect of UV-B radiation on perennial plant species.

APPENDIX D: STRATOSPHERIC OZONE DEPLETION AND HAZARDOUS AIR POLLUTANTS

Mercury Deposition in Ombrotrophic Bogs in New Brunswick, Nova Scotia and Prince Edward Island

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ABSTRACT (POSTER PRESENTATION)

Ombrotrophic or raised bogs receive all of their water and nutrients from the atmosphere and as such are well suited to record the chronology and magnitude of atmospheric deposition of heavy metals. Peat cores were collected from five raised bogs from remote areas in New Brunswick, Nova Scotia and Prince Edward Island. One core from each bog was dated using ²¹⁰Pb dating and corresponding sections from three cores from each bog were analyzed for total mercury content. Results were highly variable with no common pattern of atmospheric mercury deposition exhibited by all bogs. Three of the bogs showed a general trend of increasing mercury deposition from the mid-1800s (0.018 to 0.124 $\mu\text{g/g}$ dry wt.) until the late 1970s and early 1980s (0.083 to 0.157 $\mu\text{g/g}$), when mean mercury concentrations in peat dropped off markedly approaching pre-1850's values (0.035 to 0.051 $\mu\text{g/g}$ dry wt.). Variability in the data may be the result of sampling methods, regional atmospheric deposition patterns or mobility of mercury within the peat profile.

Atmospheric Mercury (Hg) in the Maritimes

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ABSTRACT (POSTER PRESENTATION)

Mercury is considered one of the most toxic chemicals in the environment because of its ubiquitous nature, its volatility, mobility and persistence. Mercury bioaccumulates and biomagnifies in the food chain, so small increases of mercury can be significant. Remote lakes in Maine and New Brunswick have been found to contain elevated levels of mercury. These lakes have no local sources of mercury and since the atmosphere can act as a pathway for Hg, spatial and temporal trends of atmospheric Hg in the Maritimes need to be determined. A Tekran automated Hg vapour analyzer has been set up in Kejimikujik National Park, a rural site in southwest Nova Scotia. The Tekran

APPENDIX D: STRATOSPHERIC OZONE DEPLETION AND HAZARDOUS AIR POLLUTANTS

Analyzer is based on the amalgamation of Hg on a gold trap, thermal desorption and analysis by Cold Vapour Atomic Fluorescence Spectrophotometry (CVAFS). The first continuous measurements of atmospheric Hg have been collected since August 1995. The mean concentration of atmospheric Hg from August to November 1995 was 1.8 ng/m³.

Back-trajectories as well as wind speed and direction will be used to determine source sectors of elevated levels of atmospheric Hg.

APPENDIX E

ABSTRACTS AND SUMMARIES

(IN ALPHABETICAL ORDER BY AUTHOR)

VERBAL & POSTER PRESENTATIONS FOR DAY THREE

THURSDAY 30 NOVEMBER 1995

CLIMATIC CHANGE

APPENDIX E: CLIMATIC CHANGE

Water Resources: Monitoring the Effect of Climate Change on Freshwater Ecosystems

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ABSTRACT (POSTER PRESENTATION)

To fully understand the impacts of climate change at the ecosystem level, monitoring of the change signal through its effect on water resources is necessary. It has been determined by others that changes in precipitation and temperature are amplified in the water resource. Water is a driving force in the ecosystem and as such these changes will have an impact. To ensure that the data are available to track and predict these impacts in Atlantic Canada, a network of watersheds containing long term climate and hydrometric stations has been established. Preliminary screening of data has been completed and results provided based on seasonal data only. To date, the changes noted have been due to colder winter temperatures providing a greater retention of the snowpack resulting in increased spring runoff. The noted colder winter temperatures have also increased the number of days of ice cover in the rivers. The network will provide the basis for assessing the effect of climate change in other watersheds where long term hydrometric and climate data are not both available.

Variation in Discharge, Dissolved Organic Carbon and Nitrogen Export from Terrestrial Basins with Changes in Climate: a Neural Network Approach

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ABSTRACT (POSTER PRESENTATION)

We use a neural network approach to examine relationships between climate and geography on discharge, DOC and DON from 15 river basins in Canada's Atlantic region over a ten year period extending from 1983 to 1992. Model predictions emphasize the importance of the evapotranspiration-precipitation link in establishing basin discharge, as even large increases in precipitation can lead to decreasing Q when accompanied by higher temperatures. Varying temperature and precipitation inputs to the DOC model revealed that both increases in mean monthly temperature and

APPENDIX E: CLIMATIC CHANGE

precipitation will only slightly increase exports from river basins, matching the pattern for Q. Surprisingly, lower temperatures and precipitation will also increase the exports. Increases in temperature with decreases in precipitation will lead to large decreases in export. The DON model predictions were not as accurate as DOC, but showed similar tendencies.

Methane and Carbon Dioxide Emissions from Wetlands in Pine Marten Brook Watershed, Kejimikujik National Park, Nova Scotia

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ABSTRACT (POSTER PRESENTATION)

Wetlands play a role in the global carbon (C) cycle as a source of methane (CH₄) and a sink of carbon dioxide (CO₂). As part of an ongoing study on the C cycle of wetlands in Kejimikujik National Park in south-central Nova Scotia, the aim of this study is to quantify CH₄ and CO₂ emissions from soils in two wetlands in the Pine Marten watershed and relate the emissions to variations in plant cover, water table position and thermal regime. The study provides an initial database for wetlands in Atlantic Canada. The two wetlands (1.4 and 2.1 hectares) are approximately 100 metres apart, the upper draining into the lower. Fluxes of CH₄ and CO₂ to the atmosphere were measured at 36 sites by a dark, static chamber technique from mid-July to mid-November. The study is still in progress and the results presented are those compiled till the end of September 1995.

Seasonal mean CH₄ fluxes ranged from -5 to 450 mg m⁻² d⁻¹, with an overall average of 65 mg m⁻² d⁻¹. Seasonal fluxes of CH₄ were positively correlated with water table position ($\log_{10}\text{CH}_4$, $r^2 = 0.29$, $p = 0.001$). Emissions of CH₄ were related to microtopology of the catchment. Hummocks with average water table depth > 20 cm showed the smallest emissions while wetter depression areas near stream banks with water table depth < 15 cm showed the largest.

Fluxes of CO₂ (soil respiration) ranged from 3.5 to 15.0 g m⁻² d⁻¹ with an overall average of 7.4 g m⁻² d⁻¹. Fluxes of CO₂ were negatively correlated with water table position ($r^2 = 0.15$, $p = 0.017$)

Both CH₄ and CO₂ fluxes showed large within-site variability and strong seasonal trends with marked decreases in emission rates towards the latter part of the summer and fall.

APPENDIX E: CLIMATIC CHANGE

Gas fluxes in this study are well within the range cited in other studies. The dry summer (65% of the long-term precipitation) may mean that CO₂ fluxes are larger and CH₄ fluxes smaller than usual. The findings thus underlie the importance of the effects of climatic change (through its influence on soil temperature, water table position and plant productivity) on gas fluxes from wetlands.

Significance of the Present Cooling in Northeastern Canada

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ABSTRACT (POSTER PRESENTATION)

At a time when a warming trend is being reported for central and western Canada, a number of studies have shown that surface air temperatures in northeastern Canada, from northern Baffin Island to Newfoundland, have been decreasing slightly over the past three decades. The decrease in annual temperature, with an average trend for the period of about 0.02 degrees, is found to be a result mainly of colder winters, while summers show little or no trend. This cooling trend is evident in many surface climate records from the region. Generally, however, inter-annual variability introduces so much noise into the record that the statistical significance of the trend is questionable. More conservative records, but ones equally valid as indicators of regional climate, can be obtained from subsurface ground temperature measurements as well as from ocean temperatures. These records correlate highly with air temperature records from nearby land stations. Examination of some such records for the region confirms the presence of a cooling trend in the region and, furthermore, these trends are found to be statistically significant.

The possibility of a regional cooling or reduced warming in the northwest Atlantic Ocean under anthropogenic global warming has been revealed in at least one GCM simulation. This is interpreted as a consequence of a weakening of the thermohaline convection in the north Atlantic. However, the primary cause of the regional temperature anomaly may be changes in atmospheric circulation patterns due to enhanced west-to-east tropospheric thickness differences resulting from the greater heating over the western and central regions of the continent. Support for this latter hypothesis is found in the climatology of the upper tropospheric circulation. The conclusion to be drawn is that, under global warming, the land areas of northeastern Canada as well and the adjacent ocean may continue to be anomalously cold.

APPENDIX E: CLIMATIC CHANGE

Variability of the Canadian Polar Trough and Its Connection with Anomalous Temperature Regimes over Eastern North America

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ABSTRACT (POSTER PRESENTATION)

We have conducted a short study to examine relationships between variability of the Canadian Polar Trough (CPT) and of surface temperature over eastern North America. By the Canadian Polar Trough, we mean the large-scale cyclonic circulation over eastern North America at the 50 kPa level.

We show that for the winter season (DJFM), Canada's east coast experienced a warm winter regime 1951-1960, followed by a cold regime from the early 1970's to the present. The trend and the interannual variability of winter mean temperature are found to be related to variability in the circulation of CPT. For the summer season (JJAS), this relationship is not so clear.

The mid-tropospheric analyses are based on the CMC daily, 455 gridded latitude-longitude 50 kPa data for the 48 years (1946-1993). The surface temperature analyses are derived from Jones et al. (1992), and from the Canadian maritime stations.

Climate Change Scenarios for Eastern Canada

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ABSTRACT (VERBAL PRESENTATION)

The selection and use of climate change scenarios is a fundamental step in the climate impact assessment process. Most climate impact assessments conducted in Canada have used scenarios from General Circulation Models (GCMs) since these models are the most sophisticated tools currently available for estimating the likely impacts of a doubling of atmospheric carbon dioxide. However, these global models cannot provide realistic simulations of climate change at the regional level. Some researchers have created climate change scenarios using spatial or temporal analogues, or climate statistics. Different climate change scenarios for Eastern Canada will be presented. The unique features and problems with each of these scenario types will be discussed.

APPENDIX E: CLIMATIC CHANGE

A Temperature-precipitation Departure Index as an Indicator of Climate Variability - A Case Study of the Maritime Provinces of Canada

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ABSTRACT (POSTER PRESENTATION)

Temperature and precipitation are two of the most important variables describing climate and form the basis of most climate classification schemes. While extremes of either of these elements can have severe social or economic impacts, these impacts can be either exacerbated or ameliorated when accompanied by extremes in the other. An index which combines the fluctuations in both temperature and precipitation - the Temperature-Precipitation Departure Index (TPDI) - is suggested for use as an indicator of climate variability.

Periods of high and low fluctuation can be identified from time series of the index. Time series for two long-term records in Maritime Canada for the period 1911-1990 show similarities in fluctuation and both show a marked increase in the magnitude of fluctuations since 1950. In a regional study of the Maritime Provinces, annual and seasonal time series for the period 1944-90 also indicate periods of high and low fluctuations. It is suggested that the index could be used as a tool in studies which attempt to correlate climate variability with forcing factors such as El-Nino Southern Oscillation (ENSO) events or major volcanic eruptions. The index could also be used for spatial comparisons of fluctuations for differing climate regimes

Diurnal Temperature Trends in the Maritime Provinces of Canada

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ABSTRACT (POSTER PRESENTATION)

The latest findings of the Intergovernmental Panel on Climate Change (IPCC) indicate that there has been an increase in global average temperatures of between 0.3 and 0.6 C since the late 19th Century and 0.2 to 0.3 C over the last 40 years. However, changes in maximum and minimum temperatures have not been symmetrical. There has been a general, but not global tendency, to a decrease in the diurnal temperature range (DTR) over land since the middle of the 20th century. This decrease in DTR has been due, in most cases, to a greater increase in minimum temperatures than in maximum temperatures.

APPENDIX E: CLIMATIC CHANGE

In this ongoing study of the Maritime Provinces, trends in the maximum, minimum temperatures and DTR have been investigated for three long term stations - the Canadian Department of Agriculture Stations (CDA) at Charlottetown, Fredericton and Kentville with records back as far as 1911, and for a regional data set of eight climate stations for the period 1945-1990.

On an annual basis, all three long term stations show a decrease in the DTR caused by a greater increase in minimum temperatures than in maximum temperatures. On a seasonal basis, all three showed the a marked increase in minimum temperature to have occurred in the winter months and all three showed their least increase in minimum temperatures during the fall.

For the regional data set the DTR has decreased both annually and for all seasons. However, although minimum temperatures increased in all seasons except winter, a decrease in maximum temperatures contributed significantly to the decrease in the DTR.

Future work will include expanding and investigating the quality of the datasets and attempting to investigate a cause for the perceived trends, e.g. changes in cloud cover.

Atmospheric Factors in Fluctuations in Northern Cod Stocks

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ABSTRACT (VERBAL PRESENTATION)

Evidence is presented for a strong influence of atmospheric factors on fluctuations in the Northern Cod stocks. Fluctuations in patterns of winter circulation in the atmosphere over the North Atlantic (the North Atlantic Oscillation) have led to a series of unusually cold and windy winters over the Labrador Sea. This has had the effect of forming a large body of cold water at intermediate depths and an abnormally large area of ice cover. As the water moves south in spring with the Labrador Current, the melting of the ice leads to low salinity in the surface waters and low temperatures in the waters at intermediate depth on the Grand Banks. We know from work elsewhere that these conditions lead to poor growth and survival in young cod.

While it is not disputed that overfishing was a major contributor to the demise of the Northern Cod stocks, it is probable that it was the COMBINATION of overfishing and adverse environmental conditions that caused the final collapse. There are lessons to be learned about how to manage the fisheries under global climate change.

APPENDIX E: CLIMATIC CHANGE

Decade-to-century Surface Air Temperature Trends in North American, North Atlantic, and Northwestern European Regions.

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SUMMARY (POSTER PRESENTATION)

Abstract

Annual mean surface air temperatures in eastern Canada show a cooling trend from the end of the last century to the early 1920s that was followed by warming through the 1950s. Cooling from that time to date has been particularly pronounced at Baffin Island and along the coast of Labrador. Comparison with coastal stations around the periphery of the northern North Atlantic Ocean indicates that this regional cooling is part of a general temperature decrease.

Instrumental temperature records for stations in northwestern Europe having a continuous record of over 200 years show that the warmest decade for the majority of these stations occurred before the 1980s. In the U.S. and Canada, decadal surface air temperatures show that in only 8 out of 33 defined regions was the 1980s significantly warmer than every earlier decade.

1. Introduction

The global temperature record is the principal piece of evidence available for testing the "global warming by greenhouse gas emission" hypothesis. Model climate simulations indicate greater warming in high latitude regions and more rapid warming over the land than over the oceans. As the Northern Hemisphere contains most of the land area of the globe, it is here we must look for evidence of warming. We have examined surface-air temperatures from the northern North Atlantic, northwestern Europe, United States and Canada (Fig 1) to determine to what extent temperature trends in Atlantic Canada resemble those elsewhere.

These data enable us to test the proposition that the decade of the 1980s was the warmest on record and that the most recent 30-year (1961-90) period was warmer than the preceding one (1931-60). [The 30-year period is the time interval recommended by the World Meteorological Organization for analysis of trends in climatic series.

APPENDIX E: CLIMATIC CHANGE

2. Materials and Methods

For individual stations outside North America, monthly mean surface air temperature series were obtained from World Data Center-A (Oak Ridge, TN, U.S.A.). From these were calculated annual means, annual anomalies (departures from the 1961-90 mean), decadal and 30-year means for each station. Regional means were calculated by simple averaging of stations.

The U.S. record is from 1900-92 (relative to a 1961-90 reference period) for 1221 stations. These were grouped into climatic regions based on terrain, vegetation, etc. The composite for the contiguous United States was produced by taking an areally weighted average of these values (Karl et al. 1994).

The Canadian record is from 1895-1992 (relative to a 1951-80 reference period) for 131 locations across Canada. The individual series were combined into regions (defined much like the U.S. regions) and a national series was obtained from their temporally and spatially weighted means (Findlay et al. 1994).

3. Results

a) Atlantic Canada (Fig 2)

A cooling trend from 1900 through the 1910s into the early 20s was followed by warming until the early 50s. The cooling that occurred subsequently was interrupted from the mid-70s to the mid-80s, but resumed through the latter half of the 80s to the present. The warmest decade in the region was the 50s, and the 30-year period 1931-60 was warmer than 1961-90.

b) Labrador and Baffin Island

The data-base for this sub-region is virtually non-existent prior to 1940. Since that time, there has been marked cooling consistent with declines at stations in Greenland during the same period (Fig 3).

c) Greenland

Initial cooling in the first two decades of this century was followed by a rapid rise in temperature through the 20s to the 30s (warmest decade). Persistent cooling since the early 40s has been interrupted by brief periods of warming in the early 60s, late 70s and mid-80s.

APPENDIX E: CLIMATIC CHANGE

d) Iceland (Fig 4)

Two cold decades at the beginning of this century were followed by a rapid rise through the 20s to the 30s (warmest decade). Subsequent cooling until the early 80s was interrupted by warming in the late 50s and early 70s. Warming through the 80s into the 90s has returned temperatures nearer to their initial values.

e) North Atlantic (Fig 5)

At island stations in the northern North Atlantic (45-78N), two initial cool decades were followed by a rapid increase during the 20s to three warm decades (30s-50s). Since then there has been steady cooling.

Sea surface temperature (SST) anomalies show close similarity to these surface air temperature trends though the warming in SST occurred somewhat later than for surface air temperature (Morgan *et al.* 1994).

f) NW Europe (Table I)

In this region, where the first instrumental measurements of temperature were made, time-series extending back over 200 years can be found. The warmest decade on record for the majority of these stations was not the 1980s, but either earlier in this century, or in the late 18th century. Notably, no station had its warmest decade in the 19th century, but all stations had their coldest decade in the 19th century. Thus any time-series beginning in the mid-to-late 19th century and continuing to the present day (as the global and hemispheric time-series do; Jones *et al.* 1994) cannot fail to show an overall warming. This warming is not apparent in the full 200-year record.

g) North America (Table II)

In the U.S., although the 1980s was the warmest decade of the century in 12 out of 23 regions, it was significantly so ($> 0.3^{\circ}\text{C}$) in only five of them. In contrast, temperatures were significantly cooler in the 80s than during an earlier decade in seven of the remaining 11 regions. The U.S. national record shows a small cooling on both the decadal and 30-year scales.

APPENDIX E: CLIMATIC CHANGE

In Canada, only three inland regions (Northwestern Forest, Prairies, and Southern BC Mountains) were significantly ($> 0.3^{\circ}\text{C}$) warmer in the 80s than in any earlier decade. Atlantic Canada was significantly colder in the 80s than the 50s. For Canada as a whole, the most-recent decade was the warmest - but only by 0.12°C . The 1961-90 mean is cooler than the 1931-60 mean by approximately the same amount. Warming in Canada as a whole over the past 60 years has been marginal, and the case for warming since 1885 rests upon the sparse pre-1930 record of temperature.

4. Conclusions

Surface air temperatures around the northern North Atlantic over the past decade (1981-90) have remained close to, or below, their long-term means, and well below those of the warmest decades in this century.

In northwestern Europe, the warmest decade in the record at a majority of long-term stations came before the 1980s. Many regions in North America had their warmest decade prior to the 80s. This is in marked contrast to the report that "The 1980s was a decade of unprecedented warmth ..." (Jones *et al.* 1994).

Global and hemispheric mean surface air temperature records for the period 1885-1990 are commonly used to support the argument that the world is warming at a rate - and to a degree - not seen before. This thesis is poorly supported by these regional data.

Acknowledgements

The assistance of the Climatological Section of the Atmospheric Environment Service (Bedford, N.S., Canada) and the Carbon Dioxide Information Center, Oakridge National Laboratory (Oak Ridge, TN, U.S.A.) in the provision of data is gratefully acknowledged as is the contribution of Mr. J.D. Leonard and Ms. B.E. Kehoe in the preparation of this paper.

APPENDIX E: CLIMATIC CHANGE

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APPENDIX E: CLIMATIC CHANGE

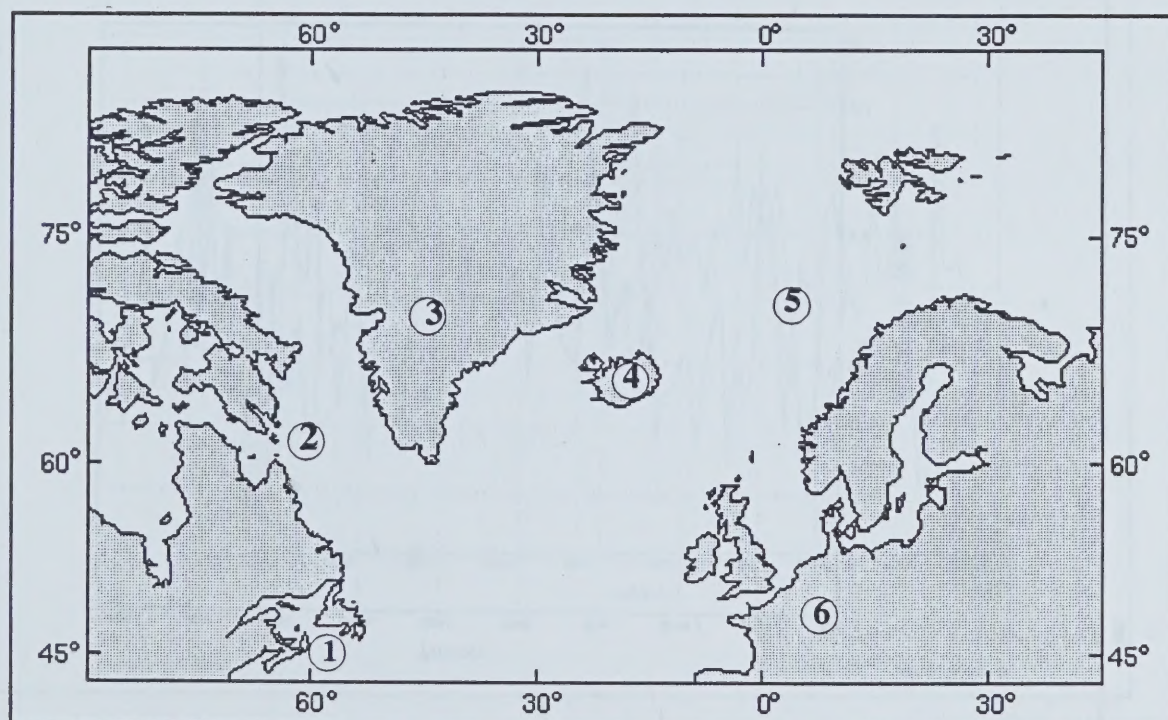


Fig 1. Areas of study around the northern North Atlantic: 1.) Atlantic Canada, 2.) Labrador and Baffin Island, 3.) Greenland 4.) Iceland, 5.) islands in the North Atlantic and 6.) NW Europe.

APPENDIX E: CLIMATIC CHANGE

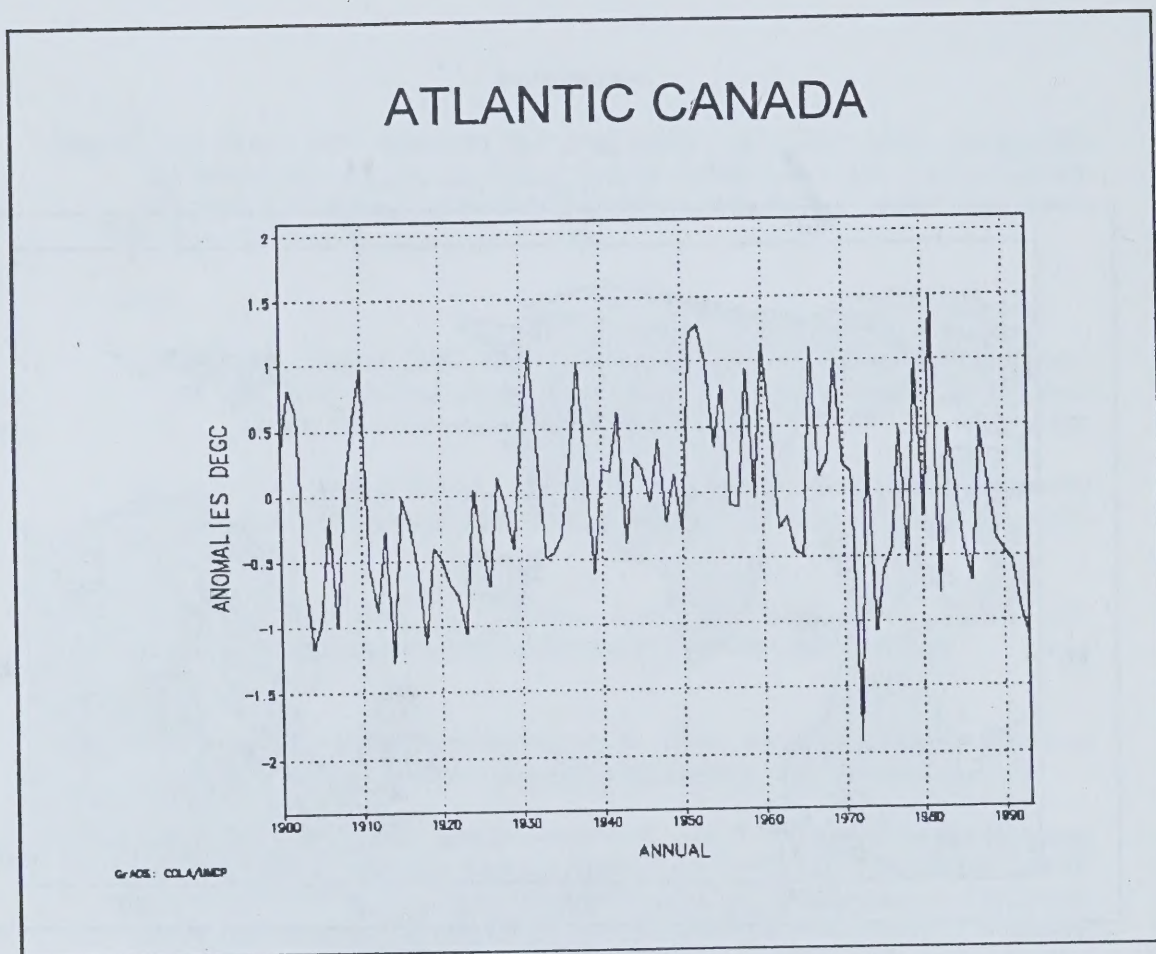


Fig 2. Annual surface air temperature anomalies 1900-93 for Atlantic Canada.

APPENDIX E: CLIMATIC CHANGE

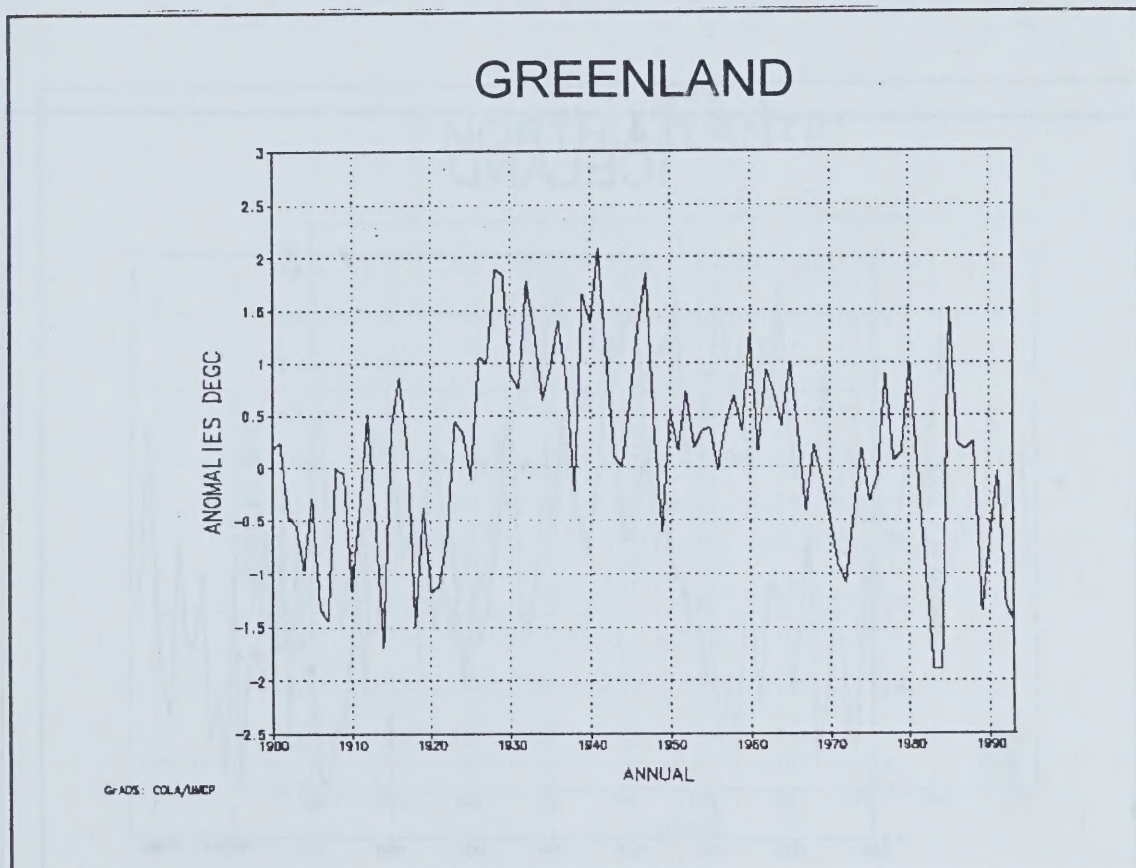


Fig 3. Annual surface air temperature anomalies 1900-93 for Greenland.

APPENDIX E: CLIMATIC CHANGE

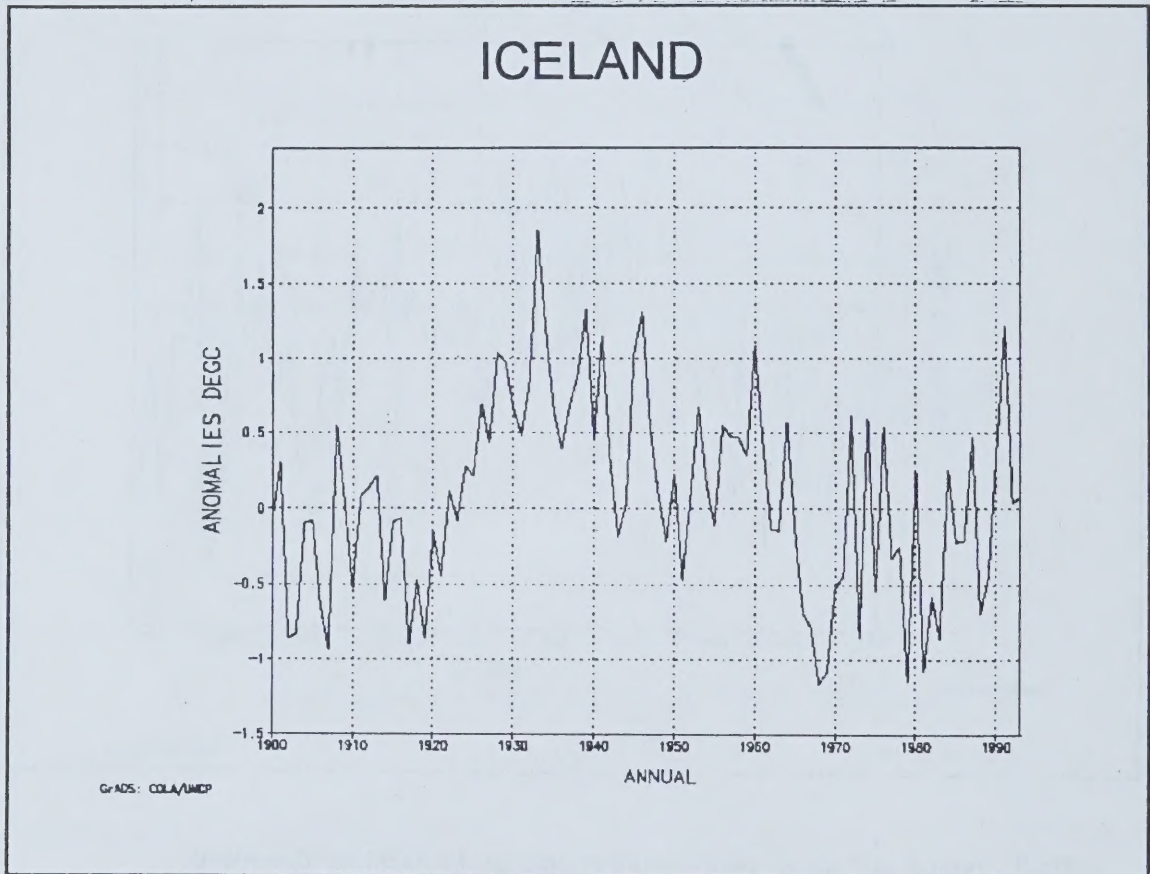


Fig 4. Annual surface air temperature anomalies 1900-93 for Iceland.

APPENDIX E: CLIMATIC CHANGE

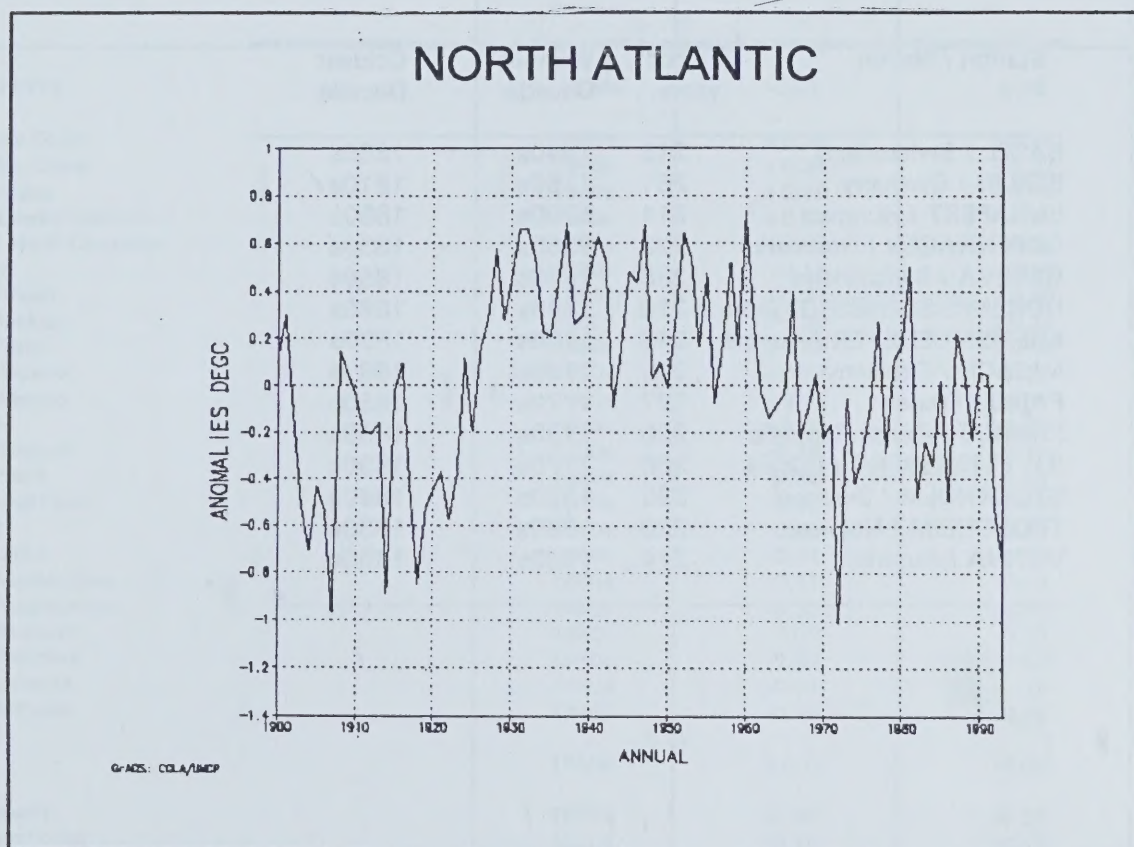


Fig 5. Annual surface air temperature anomalies 1900-93 for islands in the northern North Atlantic.

APPENDIX E: CLIMATIC CHANGE

Table I. Stations in NW Europe with a 200-year record

Station / Nation	no. years	Warmest Decade	Coldest Decade
BASEL / Switzerland	215	1940s	1880s
BERLIN / Germany	261	1750s	1810s
BUDAPEST / Hungary	211	1790s	1880s
COPENHAGEN / Denmark	223	1980s	1830s
GENEVA / Switzerland	238	1980s	1850s
HOHENPEISSENBERG/Germ.	210	1790s	1880s
KREMSMUNSTER / Austria	213	1780s	1830s
MUNICH / Germany	210	1790s	1880s
PARIS / France	227	1770s	1880s
PRAGUE / Czech Republic	220	1790s	1850s
ST. PETERSBERG / Russia	238	1770s	1890s
STOCKHOLM / Sweden	235	1930s	1860s
TRONDHEIM / Norway	220	1930s	1830s
VIENNA / Austria	214	1980s	1850s

APPENDIX E: CLIMATIC CHANGE

Table II. Regional decadal-mean surface air temperatures and normals for U.S. and Canada.

Region	Warmest Decade	Decadal Diff. (D)	Normal Diff. (N)
UNITED STATES	1930s	-0.01	-0.09
North Pacific Coast	1980s	+0.33	+0.23
South Pacific Coast	1980s	+0.31	+0.37
North Cascades	1980s	+0.16	+0.16
California Interior Valleys	1980s	+0.34	+0.35
East Slope North Cascades	1980s	+0.07	+0.14
Great Basin	1980s	+0.13	+0.17
Southern Desert	1980s	+0.31	+0.06
Northern Rockies	1980s	+0.20	+0.22
Northern Plains	1980s	+0.36	+0.04
Southern Rockies	1980s	+0.27	-0.07
Northern Steppes	1980s	+0.02	-0.01
Great Lakes	1980s	+0.08	-0.20
Southern Steppes	1930s	-0.28	-0.19
Southern Plains	1930s	-0.36	-0.28
South Coastal Plain	1930s	-0.42	-0.44
Gulf Coast	1930s	-0.48	-0.47
Eastern Prairies	1940s	-0.34	-0.43
Northern Appalachians	1950s	-0.11	-0.24
Southern Appalachians	1930s	-0.32	-0.42
Northern Piedmont	1950s	-0.02	-0.19
Southern Piedmont	1940s	-0.38	-0.52
Coastal Northeast	1950s	-0.01	-0.10
Coastal Southeast	1940s	-0.40	-0.44
CANADA	1950s	+0.12	-0.08
Atlantic Canada	1950s	-0.46	-0.29
Northeastern Forest	1950s	-0.10	-0.12
Great Lakes/St. Lawrence	1980s	+0.01	-0.17
Northwestern Forest	1980s	+0.52	+0.06
Prairies	1980s	+0.44	+0.07
Southern BC Mountains	1980s	+0.55	+0.11
Mackenzie District	1980s	+0.06	+0.01
Yukon/North BC Mountains	1980s	+0.17	-0.05
Pacific Coast	1930s	+0.02	-0.04
Arctic Tundra	1950s	-0.21	-0.12

(D) decadal mean for the 80s minus warmest decadal mean prior to 1980.

(N) normal for 1961-90 minus normal for 1931-60.

APPENDIX E: CLIMATIC CHANGE

Terrestrial Implications of Climate Change

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ABSTRACT (VERBAL PRESENTATION)

GCM projections of global climate under a stable 2xCO₂ scenario generally indicate increases in temperature and precipitation, with the greatest changes occurring in mid-continental regions at mid- to high latitudes. According to these projections, the Prairie Provinces of central Canada are likely to undergo increases in mean annual temperature in the range 4-8 °C with associated increases in annual precipitation in the order of 15-30%. Estimates of annual potential evapotranspiration (PET) for current and projected climates indicate that significant increases in growing season soil moisture deficits will occur. Changes in the Atlantic Provinces are likely to be smaller in magnitude, but may still be ecologically significant.

It would appear that the circumpolar boreal forest and tundra ecosystems, which characterise much of Canada, are particularly sensitive to such changes, not only because of environmental effects on vegetation growth, but also because of expected increases in the frequency of natural disturbances (particularly wildfires and insect infestations), and because of the effects of warming on decomposition rates in organic soils and wetlands. The latter processes may contribute to run-away feedbacks (i.e., accelerated releases of greenhouse gases from natural ecosystems), while the former may lead to major changes in the vegetation's capacity to sequester atmospheric carbon.

Clearly, the potential impacts of a warming climate on Canadian forest ecosystems are of great concern, both in terms of global climate interactions and for their regional socio-economic implications. In collaboration with other agencies, the Canadian Forest Service has developed a climate change research program to evaluate both the possible effects on forest and tundra ecosystems and the possible feedbacks from vegetation to atmosphere. This research program includes both experiments and modelling components. Some of the ongoing work and preliminary results will be discussed briefly.

APPENDIX E: CLIMATIC CHANGE

Wave and Storm Climate Variability in the North Atlantic

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SUMMARY (POSTER PRESENTATION)

Several recent extreme storm and wave events in the northwest Atlantic have exceeded published estimates of extreme wave climatology. The most notable events were the Hallowe'en Storm of Oct. 1991 and the Storm of the Century, Mar. 1993, where 16 to 17 m significant wave heights were measured by moored buoys off the edge of the Scotian shelf. It is not clear if these events are an indication of a changing wave climate, or how they relate to natural climate variability. The primary source of interannual and interdecadal climate variability in the North Atlantic is the North Atlantic Oscillation (NAO), which is associated with changes in the surface westerlies across the North Atlantic. High NAO indices indicate stronger westerlies and a deeper Icelandic low pressure centre. There has been an increasing trend in the NAO since the late 1970s, with unprecedented strongly positive NAO indices since 1980. A simple comparison of the number of major storms each winter, for the thirty year period of the published wave hindcast study, with the winter NAO index, did not show any correlation.

This presentation summarizes the results of four studies presented at the Fourth International Workshop on Wave Hindcasting and Forecasting, Oct. 16-20/95, Banff, AB. Trends in the wind and wave climate in areas of the North Atlantic, and the relationship between the wind and wave climate and low frequency atmospheric circulation patterns, are presented. No increase in wave climate was found off the east coast of the US over the last 15 years, however over the northeast Atlantic wave analyses do show an increase in significant wave height over the last 30 years. This increase is linked to corresponding changes in the sea level pressure patterns and the NAO index. More work could be done on this subject for the north west Atlantic.

Variation of Measured Meteorologic and Oceanic Variables off the US Atlantic Coast, 1980-1994, by J. Hubertz. In this study, data from 5 moored buoys in deep water off the Atlantic Coast in a 15 year period were examined. No long term trends in the wind speeds or wave heights were found. There was also no trend in "storminess" from year to year, although some years were stormier than others.

APPENDIX E: CLIMATIC CHANGE

The WASA Project: Changing Storm and Wave Climate in the Northeast Atlantic and Adjacent Seas, by the WASA (Waves and Storms in the North Atlantic) group, presented by Hans Von Storch. After resolving as much as possible inhomogeneities in the data series, their results show that statistics of significant wave height have increased significantly over the last 30 years. The increase for an area west of Ireland is about 3-4 cm/yr for the annual 10 percentile. Similar results were obtained for an area south of Greenland, including part of the Labrador Sea. However over the last century there has been considerable natural variability on the decadal time scale.

Link Between North Atlantic Climate Variability of Surface Wave Height and Sea Level Pressure, by Y. Kushnir, V. Cardone, & M. Cane, presented by Y. Kushnir. The authors relate the upward trend in significant wave height observed at the Seven Stones Light Vessel, off the southwestern tip of England (average increase 2% a year, 1962-1986) and a similar trend at Ocean Weather Station Lima (57°N/20°W) between 1975 and 1988, with changes in atmospheric pressure patterns over the North Atlantic. The NAO index, which is a measure of the strength of the pressure gradient between 50°N and 60°N, increased from the 1970s to the 1980s. This variability is consistent with the strengthening of the westerlies in this latitude belt which could have led to the change in wave height. The sea level pressure (SLP) change has been linked to the basin wide cooling of the N. Atlantic SST. In this study they try to demonstrate more clearly the link between surface wave heights and SLP on interannual and interdecadal time scales, by performing a wave hindcast and relating the results to the SLP. Their results confirm the upward trends in wave heights (and storminess) in the eastern N. Atlantic. However there were trends of decreasing wave heights further south, between 30°N and 40°N. The analysis did not show a clear relationship between mean SLP and wave height over the western Atlantic.

A Study of Relationships Between Large-Scale Circulation and Extreme Storms in the North Atlantic Ocean, by D. Resio, V. Swail, and R. Atkins, presented by D. Resio. The authors looked at possible coupling between long-term measures of atmospheric circulation and extreme extratropical storms in the western N. Atlantic. They investigated storm track characteristics and found variations in areas of cyclogenesis and in storm track locations and orientations, and in frequency of storms per decade. They found a relationship between the occurrence of particular dominant atmospheric circulation patterns and extreme wave heights. They conclude that different return period extreme waves can be expected for different categories of circulation patterns. They relate a certain circulation pattern which occurred more frequently in the 1930s and 1940s, and in the 1970-1980s, with the production of more very intense storms. The authors do not discuss how the dominant circulation patterns found in this study relate to the NAO.

APPENDIX E: CLIMATIC CHANGE

Climate Change: Calculating Forest Hydrology Conditions

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ABSTRACT (POSTER PRESENTATION)

Calculations concerning future climate conditions should be complemented by way of forest hydrology simulations, in order to better establish linkages between climate change and landscape dynamics. Knowledge about future hydrological conditions is, for example, essential for predicting future responses of forest landscapes to climate change. Pertinent aspects relate to: (1) growth and yield of forest vegetation and of wildlife and in-shore fisheries, (2) floral and faunal species shifts (uplands, wetlands, and stream corridors). The following knowledge is fundamental for each anticipated climate scenario: changing conditions in soil moisture, evapotranspiration, snowpack accumulations and durations, frost in the ground, stream discharge, soil and stream temperature, and depth and duration of frost in the ground. This poster shows how such calculations can be done in a portable yet reliable manner, based on existing forest hydrology calculations and model performance evaluations for two watershed situations: Turkey Lakes north of Lake Superior, and Kejimikujik National Park (several watersheds).
